BENTON HARBOR POWER PLANT LIMNOLOGICAL STUDIES

PART X. COOK PLANT PREOPERATIONAL STUDIES 1971

John C. Ayers
H. K. Soo
William L. Yocum

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INTRODUCTION

In Part VII (March 1971) of our report series relative to the Donald C. Cook Nuclear Station, we established the following report format:

A. COOK PLANT PREOPERATIONAL STUDIES

- A.1 Recording of Local Water Temperatures
- A.2 Study of Floating Algae and Bacteria
- A.3 Development of a Monitor for Phytoplankton
- A.4 Study of Attached Algae
- A.5 Study of Zooplankton
- A.6 Study of Aquatic Macrophytes
- A.7 Study of Benthic Organisms
- A.8 Study of the Local Fishes
- A.9 Support of Aerial Scanning

B. SURVEYS OF EXISTING WARM WATER PLUMES

C. THE ICE BARRIER AT THE COOK PLANT SITE

D. EFFECTS OF EXISTING THERMAL DISCHARGES ON LOCAL ICE BARRIERS

E. EFFECTS OF RADIOACTIVE WASTES IN THE AQUATIC ENVIRONMENT

- E.1 Gamma Scan of Bottom Sediments
- E.2 The Most Sensitive Organism for Concentration of Radwastes
- E.3 Study of Lake Michigan's Present Radioactivity Content (FINISHED)

This format remains applicable and in use, but different timing of incoming results are requiring that some parts of the format be reported at times that are incompatible with the reporting of other parts. For examples, items A.2, A.5, and A.7 constitute natural report units relative to our large scale biological surveys of the Cook Plant area and will be reported as the results become available, while sections C and D involve winter work that cannot be reported before the results are available in late spring. The other parts of the reporting format comprise, in general, an 'annual report' of the preceding year's activities and will be so treated.

The first report on our large scale biological surveys comprises Part IX (February 1972) of our reports series relative to the Cook Plant. This report has suffered delays because additional staff in phytoplankton identification and counting have had to be hired and trained, and because we have had to undergo a period of evaluation of ways in which to report the results. Adequate trained staff are now on hand, and a reporting format has been settled upon; reports of subsequent biological surveys should now make progress toward becoming contemporaneous.

Major biological surveys of the Cook Plant area were carried out on 10 July 1970 (reported in Part IX), 25 September 1970, 15 April 1971; 9 July 1971, 2 September 1971, 8 November 1971, and 12 April 1972.

A. COOK PLANT PREOPERATIONAL STUDIES

A.1 Recording of Local Water Temperatures

On 11 May 1970 a lake-water temperature sensing and recording system at the Cook Plant site was activated by Indiana & Michigan personnel. The system consists of a thermistor-equipped submarine cable extending into the lake from the water line near the north edge of the site property; the shore end of the cable connects to a multipoint recorder.

Two of the five thermistors are located approximately 300 feet from shore; the remaining three are at about 2,500 feet from shore. The spring, summer, and fall configuration of the thermistors is that they are held by subsurface floats at water depths of 2 and 4 feet at the 300-foot position and at depths of 2, 12, and 17 feet at the 2,500-foot position. For the winter of 1970-71 it had been intended to remove the subsurface floats and allow the thermistors to overwinter lying on the bottom. However, adverse weather conditions prevented this, and the thermistors were left over winter in the summer configuration. During the winter part of the circuits were broken, but others continued to function. The winter configuration of the surviving sensors was not known at last reporting (Part VII, March, 1971).

During the late spring of 1971 divers inspected and overhauled the system. They report that the thermistors were buried at different depths in the bottom, the subsurface floats having been removed by the winter ice.

On 28 July 1971, during a thunder storm, the whole system was abruptly incapacitated. Lightning apparently had struck a junction box, burning out its contents, whereupon the recorder cables shorted to ground due to failure of insulation, and the sensors were shorted out. By the time necessary repairs and parts replacements were completed, it was too late in the fall to resume operation. New or repaired sensors will be put into operation in the spring of 1972.

Table 1 presents the temperature data from the thermistor system and from the water treatment plants at Benton Harbor and St. Joseph, Michigan, all of which were collected and made available by Indiana and Michigan Electric Company personnel. Benton Harbor's intake is 3,375 feet from shore and in 40 feet of water; the St. Joseph intake is 1,490 feet from shore and in 19 feet of depth.

TABLE 1 Daily maximum and minimum Lake Michigan water temperatures at the Cook Plant site and at the Benton Harbor (BH) and St. Joseph (SJ) water plant intakes. Whole degrees Fahrenheit. Note: Blank spaces indicate that no data were obtained.

	Cook Plant										BH		SJ	
Offshore	300'				2500'						3375'		1490'	
Depth	2'		4'		2'		12'		17'		40'		19'	
Date														
3/01/71	30°	30°			33°	33°	34°	34°	34°	34°	36°	36°	33°	33°
2	32	32			33	33	34	34	32	32	36	36	34	33
3	32	31			33	33	33	32	32	32	36	36	33	32
4	32	32			33	33	33	32	32	32	35	35	32	32
5	32	32			33	33	33	33	32	32	36	35	32	32
6	38	32			33	33	33	33	32	32	36	36	32	32
7	37	36			32	32	32	32	32	32	36	36	32	32
8	36	36			33	33	32	32	32	32	36	35	32	32
9	34	34			33	33	32	32	34	34	36	35	32	32
10	36	36			33	33	32	32	33	33	36	36	32	32
11	34	34			32	32	32	32	33	33	36	36	32	32
12	33	32			32	32	32	32	33	33	38	37	33	33
13	36	35			34	33	32	32	34	33	38	38	33	33
14	37	32			36	33	35	34	36	34	39	38	34	33
15	33	32			35	35	36	36	36	36	41	39	35	33
16	32	32			35	34	35	32	36	34	40	39	36	33
17	32	32			34	34	34	34	36	35	39	38	35	34
18	33	33			34	34	34	34	36	35	40	38	35	34
19	36	34			35	34	34	34	37	36	39	38	35	33
20	36	34			33	33	34	34	35	34	38	37	33	33
21	37	37			33	33	33	33	33	33	39	37	33	33
22	38	37			33	33	33	33	33	33	38	37	35	34
23	37	36			34	34	34	33	34	34	37	37	36	34
24	38	37			34	34	34	34	34	34	38	37	34	33
25	38	38			34	34	34	34	34	34	38	38	36	34
26	37	36			34	34	34	34	34	34	38	38	36	35
27	37	37			35	35	35	34	34	34	38	37	35	34
28	37	35			34	34	34	34	35	35	39	38	35	34
29	36	35			36	36	36	36	36	36	40	39	37	34
30	36	36			36	35	36	35	36	35	39	39	35	35
31	36	36			36	36	36	36	36	36	41	39	36	34
4/01/71	36	36			36	36	36	36	36	36	41	42	38	36
2	37	36			37	37	36	36	37	36	42	42	38	37
3	37	36			37	36	37	36	37	36	42	42	38	37
4	37	37			37	36	37	37	38	37	42	40	39	37
5	38	38			36	36	37	37	38	37	41	40	40	38
6	39	38			39	38	39	38	40	39	40	40	40	37
7	39	39			39	39	39	38	39	39	41	39	38	37
8	42	40			40	39	41	40	41	40	43	41	39	37
9	44	41			42	41	42	41	42	41	45	43	43	39
10	42	41			42	41	42	41	42	41	44	43	43	41
11	42	42			42	41	42	41	42	42	46	44	42	40
12	49	45			44	44	44	43	45	44	46	46	44	42
13	44	44			43	43	44	43	44	44	47	46	46	42
14	44	44			43	43	44	44	44	44	48	46	44	43
15	44	44			43	43	43	43	44	43	46	46	44	41

	Cook Plant										BH		SJ	
Offshore	300'			2500'							3375'		1490'	
Depth	2'		4'	2'		12'		17'			40'		19'	
Date														
4/16/71	48°	44°		43°	43°	43°	43°	44°	43°		46°	45°	43°	42°
17	48	44		43	43	43	43	43	43		50	45	44	43
18	44	44		43	43	43	43	43	43		48	46	44	42
19	44	44		43	43	43	43	44	43		47	47	44	42
20	48	44		43	43	44	43	44	44		47	47	44	43
21	47	45		43	43	44	43	44	43		47	46	47	42
22	45	44		44	43	44	44	44	43		47	46	48	44
23	49	44		44	44	46	46	46	45		48	47	47	43
24	48	45		44	44	45	45	45	45		48	48	46	44
25	46	45		44	44	45	45	45	45		49	48	46	44
26	46	46		45	45	46	45	47	47		49	48	50	46
27	46	46		45	45	45	45	47	46		50	37	46	44
28	47	46		45	45	45	45	46	46		49	48	45	44
29	47	46		45	45	45	45	46	46		50	49	49	45
30	47	46		46	45	46	45	46	45		49	49	47	45
31	47	46		47	47	48	47	47	47					
5/01/71	47	47		48	48	49	49	47	47		52	49	48	45
2	47	47		48	48	49	48	47	47		52	50	49	47
3	47	47		48	48	48	48	49	48		50	50	49	48
4	47	47		48	48	48	48	49	48		51	50	49	48
5														
6	55	51		51	48	49	49	48	47		51	50	48	45
7	49	47		48	47	48	47	48	48		50	49	47	45
8	48	48		46	46	47	47	47	47		50	49	48	45
9	47	47		46	46	47	47	47	47		50	50	48	47
10	48	48		47	47	49	48	49	48		50	50	47	46
11	48	48		47	47	48	48	48	48		52	50	48	47
12	48	47		47	47	52	49	51	47		52	50	50	47
13	48	48		49	48	51	48	51	49		52	50	50	47
14	47	47		49	49	50	49	51	49		52	51	51	48
15	49	48		49	49	53	53	53	53		54	52	53	51
16	50	50		53	51	52	52	55	53		54	52	53	51
17	51	50		53	53	54	54	56	55		55	54	55	52
18	52	51		55	54	56	55	57	56		58	56	56	54
19	52	52		56	55	56	56	57	56		58	58	57	56
20	52	52		55	55	56	56	57	55		59	59	56	55
21	53	53		52	49	55	47	55	47		59	58	57	55
22	51	50		50	48	52	46	51	46		59	54	56	48
23	51	50		50	48	52	46	51	46		54	53	50	47
24	52	50		54	52	53	53	54	51		57	56	53	50
25	51	50		54	53	54	53	53	53		57	57	53	53
26	51	50		51	50	51	50	51	50		57	57	52	51
27														
28	51	50		51	50	51	50	51	50		57	57	54	52
29	51	50		51	50	51	50	51	50		57	57	52	51
30	51	50		51	50	51	50	51	50		58	56	52	51
31	51	50		51	50	51	50	51	50		57	55	52	51

	Cook Plant					BH	SJ
Offshore	300'		2500'			3375'	1490'
Depth	2'	4'	2'	12'	17'	40'	19'
Date							
6/01/71	51° 50°		51° 50°	51° 50°	52° 50°	51° 51°	56° 54°
2	72 69		51 49	51 51	51 50	53 51	58 55
3	73 57		51 51	52 52	52 52	53 52	58 56
4	64 58		51 51	52 52	53 52	52 51	57 56
5	65 58		51 51	54 52	53 52	54 51	57 56
6	68 60		56 53	59 54	59 54	59 53	60 57
7	63 60		57 57	60 59	60 59	59 57	61 58
8	63 60		58 57	60 57	57 57	61 56	60 57
9	61 58		58 57	61 58	61 58	59 56	61 58
10	73 59		55 55	55 54	56 55	58 56	60 57
11	73 61		55 55	55 55	58 58	58 57	62 57
12	79 65		56 55	56 55	57 57	60 58	62 58
13	69 65		76 63	73 62	63 61	64 60	64 62
14	68 66		76 63	63 63	78 61	62 57	63 61
15	65 64		62 62	61 61	64 63	57 54	61 58
16	64 61		63 58	61 61	61 58	58 54	59 56
17	60 60		63 63	62 62	63 60	60 55	60 58
18	65 62		63 62	63 63	62 62	67 59	64 60
19	68 65		68 68	65 65	67 67	66 64	68 63
20	76 71		71 68	71 67	71 59	69 65	69 61
21	66 57		62 58	63 63	61 58	70 52	67 54
22	73 65		68 66	68 68	68 65	57 51	52 51
23	69 69		69 68	70 70	68 68	64 57	61 51
24	72 69		68 68	68 68	68 68	65 62	61 56
25	73 67		71 68	71 69	69 69	67 63	65 56
26	73 71		72 72	73 73	72 71	66 64	63 59
27	73 71		72 72	73 73	72 71	69 65	66 60
28	73 71		72 72	73 73	72 71	71 70	67 64
29	73 71		72 72	73 73	72 71	72 70	70 62
30	78 75		75 75	75 75	75 75	74 73	72 60
31							
7/01/71	75 74		74 74	74 74	75 74	73 58	74 72
2	74 73		73 73	73 73	73 64	72 62	74 70
3	73 65		72 66	71 63	72 54	69 53	71 56
4	73 64		71 64	71 67	70 63	68 52	70 61
5	76 67		72 62	74 66	72 54	62 53	71 51
6	73 67		73 63	72 65	69 57	54 52	51 67
7	76 69		74 69	72 71	74 69	66 52	72 65
8	73 73		73 73	73 73	76 73	70 59	72 71
9	76 73		73 73	73 73	73 71	68 60	71 69
10	72 69		73 71	73 72	70 63	65 56	69 52
11	65 53		68 52	64 56	65 57	54 50	53 48
12	63 48		61 59	63 49	62 52	51 48	52 48
13	60 60		60 59	60 60	60 57	60 50	58 52
14	66 64		65 65	66 66	64 63	60 55	58 56
15	69 67		67 67	66 66	67 67	61 55	63 57
16	71 67		67 67	68 68	67 67	64 59	66 62

Offshore	Cook Plant					BH	SJ
	300'		2500'			3375'	1490'
Depth	2'	4'	2'	12'	17'	40'	19'
Date							
7/17/71	68° 64°		68° 58°	68° 68°	68° 54°	64° 61°	66° 63°
18	68 64		68 67	68 68	68 67	62 60	64 63
19	68 64		68 67	68 68	68 67	62 57	63 56
20	68 65		68 67	68 68	68 67	57 52	60 52
21	68 68		68 68	68 68	68 68	63 56	67 60
22	68 68		68 68	68 68	68 68	66 63	68 67
23	74 69		71 69	74 69	74 69	67 66	68 68
24	76 74		73 69	74 73	73 71	67 66	68 68
25	74 71		73 73	72 72	73 73	67 65	69 68
26	72 72		72 72	72 72	72 72	68 64	71 67
27	73 73		73 73	73 73	73 73	66 61	71 68
28						68 60	70 69
29						68 66	69 68
30						68 65	70 68
31						68 67	70 69
8/01/71						68 68	70 69
2						68 68	70 68
3						68 58	67 60
4						60 51	57 53
5						55 49	58 50
6						54 48	53 49
7						50 48	54 51
8						49 48	58 50
9						61 49	66 56
10						68 57	68 66
11						66 65	68 65
12						65 61	67 65
13						66 64	69 67
14						68 65	70 68
15						66 53	70 52
16						53 50	54 51
17						53 49	62 51
18						53 50	62 52
19						64 49	68 58
20						65 55	71 68
21						69 65	72 70
22						70 68	73 70
23						69 50	72 51
24						57 48	63 50
25						64 52	67 62
26						65 58	68 64
27						65 57	67 64
28						66 64	67 66
29						65 65	69 66
30						66 65	69 67
31						66 66	69 68

	Cook Plant					BH		SJ	
Offshore	300'		2500'			3375'		1490'	
Depth	2'	4'	2'	12'	17'	40'		19'	
Date									
9/01/71						67°	66°	69°	68°
2						67	66	70	68
3						68	67	71	69
4						69	68	71	71
5						69	69	72	71
6						70	69	72	71
7						69	68	72	71
8						70	63	73	72
9						70	61	72	72
10						70	62	72	69
11						70	62	72	58
12						62	53	68	54
13						66	61	70	63
14						67	54	71	60
15						62	52	68	54
16						65	57	68	64
17						65	65	68	67
18						65	57	67	59
19						56	54	60	58
20						60	58	61	60
21						62	60	64	61
22						64	62	64	63
23						62	61	63	63
24						62	61	63	62
25						62	61	63	62
26						61	61	62	61
27						61	60	62	61
28						62	61	65	62
29						63	63	65	64
30						62	60	65	63
10/01/71						58°	60°	63°	65°
02						56	58	65	66
03						56	64	65	66
04						64	64	65	66
05						63	64	65	65
06						62	64	63	65
07						61	62	63	63
08						60	61	61	63
09						60	60	60	61
10						60	60	60	61
11						60	60	59	60
12						59	59	60	60

	Cook Plant					BH		SJ	
Offshore	300'		2500'			3375'		1490'	
Depth	2'	4'	2'	12'	17'	14'		19'	
Date									
10/13/71						59°	59°	60°	60°
14						58	59	59	60
15						58	59	58	60
16						58	58	60	60
17						58	58	59	60
18						58	58	59	61
19						58	58	60	61
20						58	58	60	60
21						56	59	60	60
22						57	58	60	61
23						54	57	54	61
24						53	54	54	54
25						52	54	51	54
26						51	53	52	57
27						54	57	57	59
28						57	58	58	59
29						57	57	59	59
30						57	58	59	59
31						57	58	58	59
11/01/71						57	57	58	56
02						57	56	58	54
03						56	55	57	53
04						55	53	54	53
05						53	52	54	52
06						53	51	51	50
07						52	50	49	49
08						50	48	49	49
09						48	48	50	48
10						48	48	50	48
11						48	47	50	48
12						48	47	49	48
13						48	48	49	49
14						49	48	50	50
15						49	48	50	50
16						49	48	50	50
17						49	48	50	50
18						50	49	51	50
19						49	49	51	49
20						48	48	49	48
21						47	46	47	46
22						46	44	46	44
23						45	44	46	44
24						45	44	44	43
25						44	42	43	43

	Cook Plant					BH		SJ	
Offshore	300'		2500'			3375'		1490'	
Depth	2'	4'	2'	12'	17'	40'		19'	
Date									
11/26/71						42°	41°	43°	43°
27						42	41	43	42
28						42	41	43	42
29						42	41	42	40
30						41	41	42	41
12/01/71						41	39	41	40
02						39	39	40	40
03						39	38	40	40
04						40	39	41	39
05						39	39	41	40
06						40	39	40	40
07						39	39	40	39
08						40	39	40	39
09						40	39	40	40
10						40	39	41	40
11						40	40	40	39
12						41	40	39	39
13						40	39	41	40
14						40	39	40	40
15						41	39	41	40
16						40	39	40	40
17						39	38	40	38
18						38	37	39	38
19						36	36	38	37
20						36	34	37	37
21						37	36	38	37
22						36	36	37	36
23						36	35	36	36
24						36	35	37	36
25						36	36	38	37
26						37	35	38	38
27						37	37	38	38
28						37	35	38	36
29						36	35	36	36
30						35	35	37	36
31						35	35	37	36
1/01/72						35	34	34	34
02						35	35	36	36
03						35	35	36	36
04						35	34	36	35
05						34	33	35	34
06						36	32	34	33
07						36	34	34	32

	Cook Plant					BH		SJ	
Offshore	300'		2500'			3375'		1490'	
Depth	2'	4'	2'	12'	17'	40'		19'	
Date									
1/08/72						36°	35°	34°	33°
09						36	35	34	33
10						35	35	34	33
11						36	35	34	34
12						36	35	34	34
13						36	35	34	33
14						36	34	33	32
15						34	33	32	32
16						34	33	32	32
17						34	33	32	32
18						34	33	32	32
19						34	34	33	32
20						34	34	32	32
21						34	33	32	32
22						34	33	32	32
23						34	34	32	32
24						34	34	32	32
25						34	33	32	32
26						34	33	32	32
27						34	33	32	32
28						34	33	32	32
29						34	33	32	32
30						34	33	32	32
31						33	33	32	32
2/01/72						34	33	32	32
02						34	34	32	32
03						34	34	32	32
04						34	33	32	32
05						33	33	32	32
06						34	33	32	32
07						33	33	32	32
08						33	33	32	32
09						34	34	32	32
10						34	34	32	32
11						34	34	32	32
12						34	34	32	32
13						34	34	32	32
14						34	34	32	32
15						34	34	32	32
16						34	34	32	32
17						34	34	32	32
18						34	34	32	32
19						34	33	32	32
20						34	33	32	32

	Cook Plant					BH		SJ	
Offshore	300'		2500'			3375'		1490'	
Depth	2'	4'	2'	12'	17'	40'		19'	
Date									
2/21/72						34°	33°	32°	32°
22						34	33	32	32
23						34	33	32	32
24						33	33	32	32
25						34	33	32	32
26						34	34	32	32
27						34	34	32	32
28						34	34	32	32
29						34	34	32	32
3/01/72						34	36	30	31
02						33	36	32	32
03						33	35	33	33
04						34	36	32	33
05						33	35	32	32
06						33	35	32	32
07						34	35	32	32
08						33	36	32	32
09						33	35	32	32
10						33	35	32	32
11						34	35	32	33
12						34	36	32	34
13						34	36	33	35
14						34	36	33	34
15						34	36	32	33
16						35	36	32	33
17						35	36	32	33
18						35	36	32	32
19						35	37	32	33
20						35	37	32	34
21						36	37	34	35
22						35	37	32	35
23						35	35	33	33
24						35	36	33	35
25						35	35	35	36
26						35	35	34	36
27						35	36	34	37
28						35	35	34	36
29						35	36	34	37
30						35	36	33	34
31						36	38	34	35

A.2 Study of Floating Algae and Bacteria

Large scale biological surveys of the Cook Plant area, involving emphasis on this item were carried out on 10 July 1970 (reported as Part IX of our report series, February 1972), 25 September 1970 (data work-up nearing completion), 15 April 1971 (most data worked up), 9 July 1971 (some data worked up), 2 September 1971 (some data worked up), and 8 November 1971 (some data worked up), and 12 April 1972.

The degree to which the St. Joseph River might be a factor in determining the phytoplankton composition of the Cook Plant area has been a question of interest for some time. Dr. Eugene F. Stoermer has provided a list of river-associated phytoplankters which he considers would, if they were heavily dominant in our Cook Plant surveys, indicate an undesirable amount of influence of the river in the environs of the plant. These phytoplankters number 13 and are listed in Table 2.

Table 2. River-associated phytoplankters apt to be indicative of influence of the St. Joseph River in the Cook Plant area.

Amphora ovalis	*Navicula decussis*
Amphora sp.	*Navicula gastrum*
Cyclotella meneghiniana	*Navicula* sp.
Melosira granulata	*Nitzschia acicularis*
Melosira granulata v. *angustissima*	*Nitzschia* sp.
Navicula capitata	*Synedra ulna*
Navicula costulata	

Our 54-station phytoplankton collections in the Cook Plant area on 10 July 1970 have been scrutinized for the presence and degree of numerical dominance of these species.

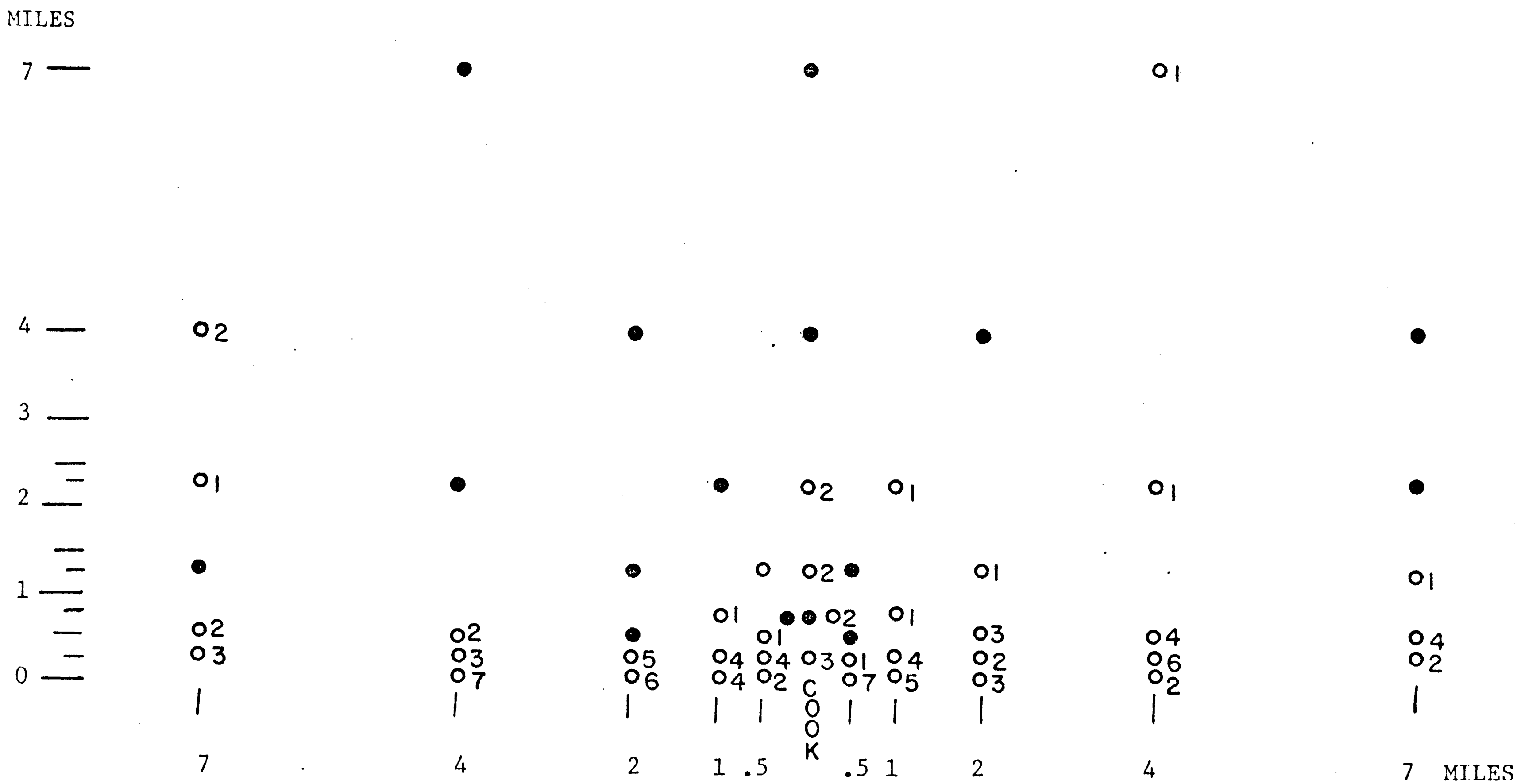
No station exhibited the required heavy dominance in numbers (the worst case was at Station NDC-4-2 where the dominant form was *Melosira granulata* v. *angustissima* which comprised 19.9% of the population).

In no station did all 13 of the riverine species occur.

In 16 of the 54 stations none of the proscribed species occurred.

When numbers of these 13 species are plotted on the chart of Cook Plant sampling stations (Fig. 1), the only pattern that emerges is of their more frequent occurrence in shallow water, a not-surprising result for these species, also known as shallow-water lake plankters.

The evidence from the 10 July 1970 survey shows no demonstrable effect of the St. Joseph River on the Cook Plant phytoplankton. However, the possibility remains, and similar analysis will be made for each of the subsequent surveys.



● = River associated phytoplankton not present.

○ = River associated phytoplankton present. (The number of river associated species observed is indicated by the adjacent number.

FIGURE 1. Cook Plant sampling stations and distribution of river associated phytoplankton.

A.3 Development of a Monitor for Phytoplankton

During the fall of 1970 and spring of 1971, we attempted to develop the optics and electronics of a dual particle and flourescent counter. We were faced with a series of setbacks in our optical arrangements and were not able to obtain the proper signal for the flourescent particles. Further attempts to develop the optics were abandoned since the cost greatly exceeds our estimate without guarantee of success.

E. Leitz Inc. has since marketed a new optics for their Ortholux series microscope in flourescence work. The new system (Ploem Opak) with the proper optics and filters costs about $7,000. It is more reasonable to expand on their system in developing the monitor than to develop our own optics. Recent additional requirements are more directly applicable to the Cook Plant preoccupational surveys than is this project; the project has been placed in abeyance and funds which it would have used have been transferred to support of the increased biological work.

A.4 Study of Attached Algae

On 11 May 1971 a total of four periphyton collectors, each bearing duplicate collecting surfaces, were set in 15 and 30 feet of water depth along the north and south property boundaries of the Cook Plant site.

The periphyton collectors were built after a design kindly furnished by Dr. James G. Truchan of the Michigan Water Resources Commission staff. They differed from his design only by being attached to the bottom by screw anchors and in the use of streamlined foam-filled fiberglass surface buoys. From the screw anchor in the bottom a generously premeasured length of chain reached up to a welded cross of 3/16 inch iron rod with welded eyes at the ends of the upper and lower arms of the cross and 4-inch threaded areas at the ends of the side arms. The chain was shackled to the lower arm of the cross,while the upper arm was shackled to an eye welded in the lower end of a 3/16 inch iron rod running lengthwise through the surface buoy to a threaded area where a washer and nut with burred threads secured the buoy. The actual periphyton collectors were of white high density styrofoam nominally 2 inches thick and cut in squares about 2 1/2 inches on a side (after sanding smooth). The styrofoam squares were mounted on the side arms of the cross between inner and outer washer-and-nut pairs. The outer nut on each side arm was a wing-nut to allow easy removal of the collector block (for scraping in the laboratory) and easy replacement of new collector blocks. In the installed condition the buoy laid over to wave and/or current action bringing the collector blocks to about 6 inches to 1 foot below the water surface. The mounting of the collector blocks provided four rectangular collecting surfaces per block; the duplicate blocks under each buoy allowed one to be used for species identification and one for determination of periphyton growth rate.

It had been planned to collect samples by changing collector blocks each month, but attempts to do so in available time in June and July were thwarted by windy weather. On 10 August the blocks were successfully changed and the samples obtained. After August the weather worsened, and available time became less as student help returned to classes. Furthermore, the surface buoys of the collectors began disappearing and by the end of October were all gone. One buoy later recovered from the beach showed that the upper washer and nut of the through-rod had worn down through the whole length of the buoy, allowing it to slip free and to drop the chain and collectors to the bottom. Another type of buoy in which this sort of failure is prevented has been designed and prepared.

The Periphyton Results: The four stations were designated by north or south side of the plant site and by depth of water when set (by lead line), while the duplicate collector blocks were called A and B. Thus, sample N30B was from the north side of the plant site in 30 feet of water and was the sample randomly selected from the pair to be used for determination of rate of periphyton growth; sample S15A was from the south side of the plant site in 15 feet of water and that selected for species identification.

The results obtained for periphyton growth during the 3-month exposure of the collectors are given in Table 3.

TABLE 3. Collectors' areas, total dry weights, and apparent average monthly growth of periphyton off the Cook Plant during the three months 11 May to 10 August 1971.

Collector	Collector's total area, cm^2	Periphyton dry weight, mg	Apparent average periphyton growth, mg dry weight/cm^2/month
N15B	128	932	2.5
S15B	123	512	1.3
N30B	121	1,667	4.5
S30B	122	1,020	2.7

The most definite thing evident in these results is that the Cook Plant area will support growth of periphyton if solid substrates are available, ergo, there should be no solid debris left along shore or in the offshore water at the end of construction.

These partial results suggest a diminished ability of periphyton to grow as the shore is approached. This is probably an effect of wave action.

Whether the greater growth of periphyton on the north side of the plant site reflects an effect of the St. Joseph River is a matter that will be kept under scrutiny. In our macrophyte surveys of 1970 and 1971 (later in this report), the divers have reported washed-in materials, probably from the river, on the bottom. These, however, could have been brought in by the occasional northwest storms and might not indicate permanent river influence in the plant area. Our analysis of the phytoplankton results of the 10 July 1970 survey which was carried out under northwest wind did not indicate riverine influence in the phytoplankton of the Cook Plant area.

1972 Periphyton Studies

On 14 April 1972 periphyton collectors similar to those used by the Water Quality Section of the Michigan Water Resources Commission were set in 15 and 30 feet of water opposite the north and south boundaries of the Cook Plant site. It is planned that the high-density styrofoam collector blocks from these sets will be removed for analysis on about a monthly basis. This style of collector exposes the collecting surfaces in the upper foot of water. The basic design of this sort of collector was provided by Dr. James G. Truchan.

A.5 Study of Zooplankton

Until 1 March 1972 our zooplankton studies have had to be delineations of zooplankton abundances by rather large "family" groups. Dr. James Roth has now joined our staff and will be in charge of species-identification in both our older reference collections and subsequent new collections.

Zooplankton was collected in each of our major Cook Plant surveys on 10 July 1970, 25 September 1970, 15 April 1971, 9 July 1971, 2 September 1971, and 8 November 1971. Each of these surveys will be the basis of a separate biological survey report (the survey of 10 July 1970 comprises Part IX of our report series).

The following is a list of the Zooplankton species we have seen in the samples from the Lake Michigan Environmental Survey. This list is for all stations lumped together.

Rotifers

Asplanchna sp. (probably *Asplanchna priodonta* Grosse)

Other species of rotifers are too small or fragile to be collected quantitatively by the techniques used and have not been recorded.

Cladocera

Leptodora kindtii Focke

Polyphemus pediculus (Linné)

Holopedium gibberum Zaddach

Bosmina longirostris (O. F. Müller)

Daphnia retrocurva Forbes

Daphnia longiremus Sars

Daphnia galeata mendotae Birge

Diaphanosoma brachyurum (Liéven)

Sida crystallina (O. F. Müller)

Eurycercus lamellatus (O. F. Müller)

Ceriodaphnia reticulata (Jurine)

Chydorus sphaericus (O. F. Müller)

Alona (species not identified)

<u>Cyclopoid copepods</u>

Cyclops bicuspidatus Claus

Tropocyclops prasinus (Fisher)

Cyclops vernalis (Fisher)

<u>Calanoid copepods</u>

Diaptomus oregonensis Lilljeborg

Diaptomus ashlandi Marsh

Diaptomus minutus Lilljeborg

Diaptomus sicilis S. A. Forbes

Eupytemora affinis (Poppe)

Epischura lacustris S. A. Forbes

Senecella calanoides Juday

Limnocalanus macrurus Sars

A.6 Study of Aquatic Macrophytes

On 21 October 1971 the bottom off the Donald C. Cook Plant was surveyed for macrophyton (rooted aquatic plants). An 18 foot pontoon boat owned by the Indiana and Michigan Electric Company was used as the support vessel from which this work was conducted.

The support vessel proceeded to a position directly off the North Range Pole to a depth of 5.5 meters and ran the first transect out to a depth of 16.5 meters. The support vessel moved approximately 457 meters south of the first transect and conducted transect number two from a depth of 16.5 meters to 4.9 meters. Transect number three was run out to a depth of 16.8 meters. The support vessel then moved approximately 457 meters north of transect number three and completed transect number four which started at a depth of 15.2 meters and proceeded in toward shore to a depth of 4.9 meters.

The support vessel was powered by a 10 horsepower outboard engine and towed the diver along the four transects (Fig. 2) at approximately 2 knots. The towing apparatus consisted of 30 meters of quarter inch polyethylene line tied at one end to a bridle on the support vessel. A handle attached to the other end of the two line allowed the diver to hold on to the line with either one or two hands.

Surface supplied diving equipment was used for this survey. Air was supplied by a high pressure cascade system located on the support vessel. A hard wire communication system was used to relay the diver's observations to surface personnel. The diver wore a variable volume dry suit which allowed the control of displacement and buoyancy.

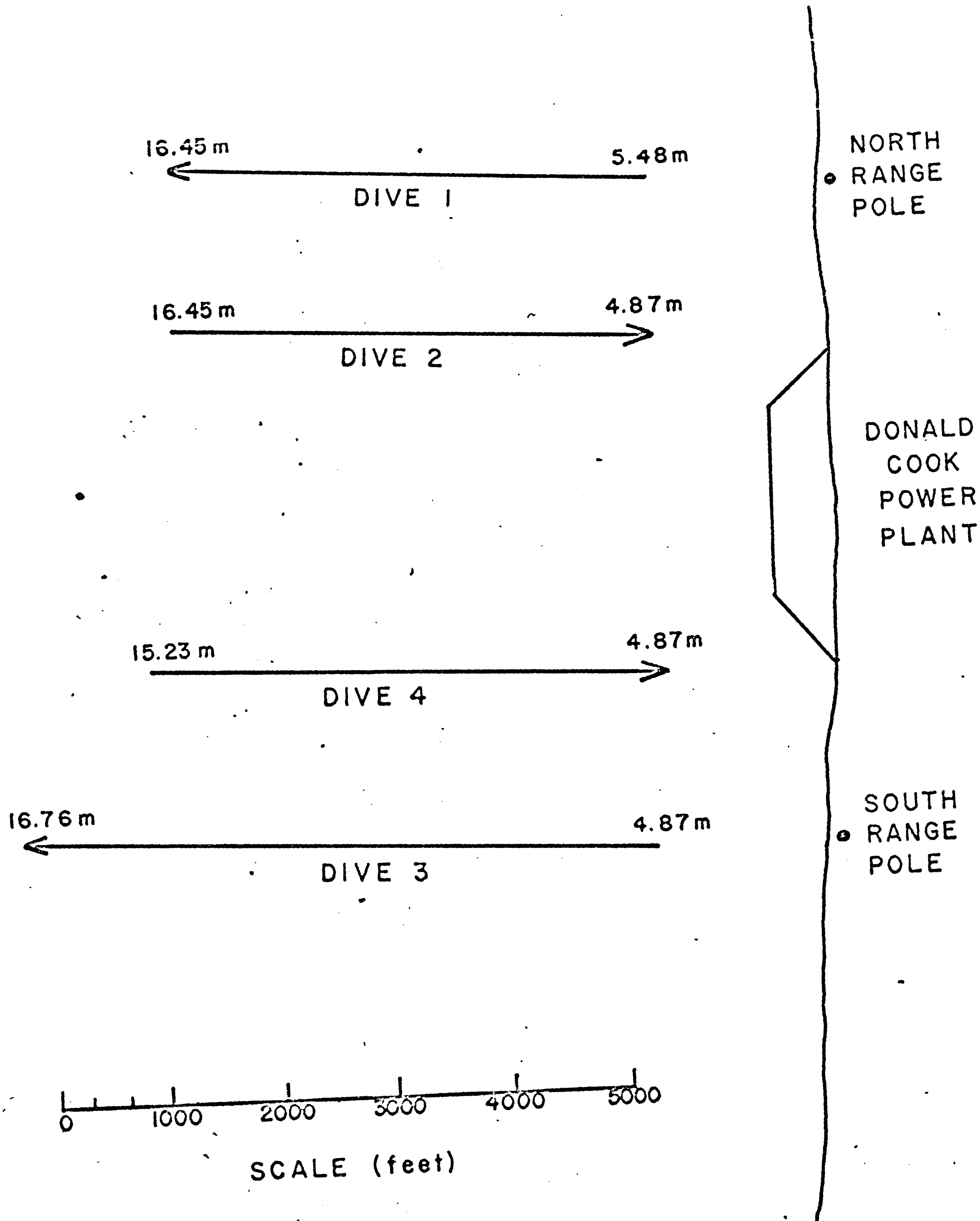


FIGURE 2. Sketch of diving locations. Macrophyte survey, 21 Oct. 1971.

Date 21 October 1971 Dive No. 1

Location Transect No. 1 - directly off the North Range Pole

Depth 5.5 to 16.5 meters

Team Diver - Robert F. Anderson

Tender - Richard A. Alpers

Dive time 31 minutes

The bottom type at 5.5 m was sand with bifurcating ripple marks present. Passed over two sandbars in which large amounts of detritus, composed mainly of *Cladophora* had collected. A large stump was also observed in the area of the two sandbars at a depth of 7.6 m. A large patch of *Cladophora* was found around the stump. The *Cladophora* observed in the vicinity of the two sandbars was not growing in place but had been washed into the area. Large bifurcating ripple marks in the vicinity of the two sandbars had wave lengths of .61 m and heights of 15 cm. A light brown layer of organic material was found in the troughs between the ripple marks. The water temperature at 7 m was 16.7°C and the visibility was between 3 and 4 m.

At 7.3 m the bottom type was sand with bifurcating ripple marks having wave lengths of 10 to 15 cm and heights of 2.5 to 5 cm. A layer of brown organic material had collected in the troughs of the ripple marks. Bottom visibility was reduced to about 2 m at a depth of 11.3 m. Bifurcating ripple marks same as those described at 7.3 m. More organic material present in the troughs than observed at shallower depths.

Bottom type at 12.2 m was clean sand exhibiting bifurcating ripple marks. Fine layer of brownish green organic material was found in the troughs between ripple marks.

Water temperature at a depth of 12.8 m was 11.1°C and the visibility on the bottom was about 2 m. Observed 2 patches of grey silt about 2 m in diameter and 5 to 8 cm in depth.

The bottom type at 13.4 m was sand exhibiting bifurcating ripple marks. Passed over a patch of silt 1 m in diameter.

Passed over several patches of dark grey silt about 3.5 m in diameter and 5 to 8 cm deep at a depth of 14.02 m. Visibility was reduced to between 1 and 2 m at a depth of 14.3 m. Bifurcating ripple marks with wave lengths of 7 to 10 cm and heights of 2.5 cm observed at a depth of 14.3 m. Observed several patches of dark grey silt 2.5 to 3 m in diameter.

Passed over several more patches of dark grey silt at a depth of 15.2 m that varied from 1.5 to 3 m in diameter. The water temperature at 15.2 m was 10°C and the visibility was reduced to 1 m.

The bottom type at a depth of 16.5 m consisted of a sandy silt. The ripple marks were quite small at this depth but a heavy layer of organic material was observed in the troughs between the ripple marks.

Small black areas of organic material 5 to 8 cm in diameter were observed on the surface of the dark grey pockets of silt found along this transect.

Observed a school of young alewives near the start of this transect. No macrophytes were observed on transect number one.

Date 21 October 1971 Dive No. 2

Location Transect No. 2 - 457 meters south of Transect 1

Depth 16.5 to 4.9 meters

Team Diver - Robert F. Anderson

Tender - Richard A. Alpers

Dive time 28 minutes

Bottom type at a depth of 16.5 m was a silty sand. Passed over several pockets of silt 1 to 3 m in diameter and 5 to 8 cm in depth between 16.5 and 14.6 m.

Bottom type at a depth of 14.6 m was sand with bifurcating ripple marks present. Bifurcating ripple marks at a depth of 13.4 m had a wave length of about 15 cm and a height of 4 cm. Bottom type at 13.4 m was sand with a thin layer of organic material in the troughs of the ripple marks. Bifurcating ripple marks still present at 11.9 m with a thin layer of light brown organic material in the bottom of the trough. No patches of silt were observed.

Bottom type at 10.7 m was a clean sand with ripple marks. Observed numerous fingernail clam and snail trails in the silt and organic material between the ripple marks at a depth of 9.8 m. Bottom type at 9.8 m was sand with the ripple marks spaced closer together. No patches of silt observed in this area. Did not observe any chunks of peat that were quite abundant in this area last year. Bottom water temperature was 16.7°C. Ripple marks present at a depth of 7.6 m. Bottom type was a clean sand with very little detritus observed. At 7.3 m bifurcating ripple marks had a wave length of 5 to 8 cm with a fine layer of organic material in between the troughs. Bottom type at 6.7 m was sand with ripple marks. Observed a small patch of loose *Cladophora* 5 cm in diameter.

Large ripple marks were observed at a depth of 7.6 m with a heavy accumulation of detritus and pieces of wood in the troughs. Observed a large mat of *Cladophora* in this area. The *Cladophora* was not growing in place but had been washed into the area.

Bottom sloping rapidly upward from a depth of 7.6 m to 4.6 m. Large bifurcating ripple marks were observed at 4.6 m with a wave length 20 to 30 cm and a height of 5 to 8 cm. Patches of light brown organic material found in the troughs.

No macrophytes were observed along transect number 2.

Date 21 October 1971 Dive No. 3

Location Transect No. 3 - directly off the South Range Pole

Depth 4.9 to 16.8 meters

Team Diver - Robert F. Anderson

Tender - Richard A. Alpers

Dive time 33 minutes

The bottom type at a depth of 4.9 m was composed of a clean sand exhibiting large bifurcating ripple marks. The ripple marks had a wave length of 15 to 20 cm and a height of 5 to 8 cm. Very little detritus was observed in the shallow depths of this transect. A thin layer of organic material was present in the bottom of the troughs. The bottom type at 7.6 m was sand with the ripple marks becoming smaller.

Several pockets of silt were found between the depths of 9.1 and 16.8 m. The size of the silt pockets varied from 1 to 2.4 m wide and 10 to 15 cm deep. Black patches of organic material were scattered over the surface of the silt pockets.

The bottom type in the depth range from 12.2 to 16.8 m was a sandy silt. The ripple marks were not as well developed in this area. Dive was terminated at a depth of 16.8 m.

No macrophytes were observed along transect number 3.

Date 21 October 1971 Dive No. 4

Location Transect No. 4 - 457 meters north of Transect 3

Depth 15.2 to 4.9 meters

Team Diver - Robert F. Anderson

Tender - Richard A. Alpers

Dive time 28 minutes

The bottom type between the depths of 15.2 and 12.2 m consisted of a sandy silt with small bifurcating ripple marks. A thin layer of brown organic material was observed in between the troughs. The ripple marks were small and not well developed in this area. Observed many small circular depressions in the bottom.

Visibility at 13.7 m was about 1 m and the water temperature was 14.4°C. Passed over a pocket of silt 1.2 m in width.

At 12.2 m the visibility improved slightly to 1.8 m and the water temperature was 16.7°C. Observed another pocket of silt 2.4 m in width with small patches of black organic material scattered about the surface.

Bifurcating ripple marks at a depth of 10.7 m were spaced about 7 to 10 cm apart. Fingernail clams and snail trails were quite common in the silt and organic material present in the troughs between ripple marks.

Passed over a chunk of fibrous peat at a depth of 10.7 m. Observed 2 patches of light grey silt about 1.2 m wide.

Bottom type at 8.5 m was sand with a lot of organic material on the bottom. Bifurcating ripple marks still 7 to 10 cm apart with a layer of organic material in the troughs. Bifurcating ripple marks have a wave height of 2.5 cm. Observed several pieces of fibrous peat at a depth of 7.6 m.

At 6.7 m observed several patches of *Cladophora* that had been washed into the area. Passed another school of young alewives. Bottom in this area contained no ripple marks.

Bifurcating ripple marks with a wave length of 15 to 20 cm and a height of 5 to 8 cm observed at 4.9 m. Clean sand bottom with very little detritus present.

No aquatic macrophytes were found along transect number 4.

A.7 Study of Benthic Organisms

Although studies of benthic organisms will henceforth usually be a part of the reports on each of our major biological surveys of the Cook Plant area, Dr. Samuel C. Mozley has contributed the following timely note that confirms late spring (May) spawning and die-off of adult females of the amphipod *Pontoporeia affinis* in the Cook Plant area. This phenomenon had been found in other shallow parts of Lake Michigan previously by Alley (1968)[1], but Mozley's note establishes it as a part of the biological cycle at the Cook Plant as well. Dr. Mozley's note follows in its entirety.

Pontoporeia Observations in April and May, 1971

S. C. Mozley

Collections with an epibenthic sled-dredge were made on April 16, and May 18, 1971 at depths of 80-130' (25-40 m) at a location approximately 6 miles (10 km) west-southwest from Benton Harbor. The bottom was uneven at depths of about 80', then sloped smoothly downward offshore beginning at a depth of about 100'. Clay and silt were major sediment constituents at 130', but silty sand predominated at 100'. The sled-dredge caught large numbers of *Pontoporeia* and some *Mysis* and sphaeriid clams, but the mesh size of the net or the depth of its bite were insufficient to catch oligochaetes. April tows were at greater speeds during quiet weather because the sled was pulled at minimum ship's speed of 2 kts. In May, when the boat was allowed to drift downwind (about

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[1] Alley, W. P. 1968. Ecology of the burrowing amphipod *Pontoporeia affinis* in Lake Michigan. Univ. Mich., Great Lakes Res. Div., Spec. Rep. 36, 121 p.

200 yds in 10 minutes), the towing speed was much slower. The sled-dredge was in contact with the bottom for the entire tow in May, as indicated by constant strain on the cable. In April the device seemed to be bouncing or skipping irregularly over the bottom due to the faster speed. While some *Pontoporeia* appeared to be injured during collection in April, there was a high percentage of surviving amphipods, including many gravid females.

In May, however, over 95% of the *Pontoporeia* were dead or moribund when the sled-dredge reached the surface, and many were covered with a thick layer of filamentous fungi and bacteria. Closer examination showed that, with two exceptions, none of the surviving *Pontoporeia* were gravid females--most being 5-6 mm long. As far as it was possible to determine the sex of badly decomposed animals, they were spent females. A majority of the other dead *Pontoporeia* which were in the first stages of decomposition--muscular disintegration and translucence of the body--were also spent females, but this less decomposed category included all size classes. Injury of shock during the sampling procedure cannot be ruled out as a cause of death of animals in this condition.

Alley (1968) states that the single sexually mature instar of *Pontoporeia affinis* is the last one, and females begin to degenerate even before all young are released from the marsupium. Signs of decomposition he observed were also present in May specimens--swollen, milky gills and body translucence. It is proposed that such massive die-offs are a normal feature of the *Pontoporeia* life cycle, at least for the adults. The late spring timing coincides well with Alley's determination of the breeding period (late winter - early spring) for *Pontoporeia* populations in shallower water of southern Lake Michigan. His data from 1965 show a strong shift in size frequencies of this population, from larger to smaller amphipods, between May and early June.

Smaller *Pontoporeia* were observed to cling to decomposing adults in the laboratory. Massive deaths of adults may provide an important food source for young *Pontoporeia* in this area, and result in considerable retention of caloric energy within the population which might otherwise be lost to bacteria or microfauna.

Benthic Macrofauna in the Coastal Zone of Southeastern Lake Michigan

Further studies of benthic organisms supported by the Indiana and Michigan Electric Company have been submitted as a manuscript to the Proceedings of the 15th International Conference on Great Lakes Research, 1972, entitled "Benthic Macrofauna in the Coastal Zone of Southeastern Lake Michigan" by S. C. Mozley and L. C. Garcia. The abstract of the manuscript with minor corrections is reproduced as follows.

Abstract. In July 1970, the first of a continuing series of of benthos surveys was conducted in southeastern Lake Michigan in an area centered 16 km south of Benton Harbor. This report contains the species composition and abundances from that survey. The 23-by-11-km area along the shore exhibited a clear gradient in total benthos abundance, which was correlated positively and significantly with depth between 4 and 25 m. Imposed on this gradient was a series of faunal zones characterized by (1) four types of chironomids (4-6 m), (2) *Pontoporeia affinis*, *Sphaerium striatinum*, and *Limnodrilus hoffmeisteri* (8-15 m), and (3) *Pontoporeia*,

Stylodrilus heringianus, *Sphaerium* sp. 1, and *S. nitidum* (20-25 m). Intermediate depths had mixtures of the animals from adjacent zones. A concentration of several taxa in the center of the survey area corresponded to a large shallow depression in the bottom. Altogether, 38 taxa were distinguished, and only the genus *Pisidium* was not broken down into species or larval types. Comparisons of the types of chironomids and oligochaetes with other areas in the Great Lakes revealed a mixture of "oligotrophic" and "eutrophic" conditions, as defined by indicator species. There were small but important differences in the species composition between the survey area and similar parts of Lake Ontario. Application of a standard species diversity index to the samples provided little additional insight into the ecology of the area, and values varied so much that their significance was ambiguous.
(Key words: Benthos, macrofauna, Lake Michigan, coastal zone.)

Studies of the Psammo-littoral Community

The microscopic animals living between the sand grains in Lake Michigan beaches may be subject to elevated temperature levels when cooling water from the Donald C. Cook Nuclear Power Plant is released into the lake. This series of studies is intended to determine pre-operational composition and abundance of these animals in the various seasons and beach levels both above and below the water line. This habitat has rarely been investigated in the Great Lakes, and never in detail, so a preliminary series of exploratory sample sets must be analyzed before a useful monitoring program can be established. The following is a report of the first exploratory samples.

Two areas were sampled. At the Donald C. Cook Plant, five sites were sampled with a variety of instruments just north of the North Range Marker (Fig. 3) on Jan. 31, 1972. Fully developed ice ridges abutted the coast, and there was no open water near shore. At the Campbell Plant, a fossil-fuel generating station near Port Sheldon on the Lake Michigan coast, samples were taken in frozen beach sand, wet sand at the water line, and at a depth of 10 cm below the water line along a transect in the mouth of the heated effluent channel (Fig. 4) on Feb. 1, 1972. The ridges protected the mouth of the channel, but a large area around the mouth was ice-free. The sampling procedure at each location is given as follows.

COOK PLANT

1. Outer Beach - 4 m from presumed water's edge; a hole 20 cm in diameter was drilled through frozen sand for 30 cm with a posthole auger, then farther down to the water line (water level in hole) at 85 cm below the sand surface. Three cores of 5 cm diameter were taken from the water line to a depth of 10 cm below it. Interstitial water was probably anaerobic. All samples were kept on ice in a styrofoam container until the animals could be extracted.
2. Middle Beach - 0.5-1 m from presumed water's edge. Two samples were taken with conduit pipe about 3.8 cm in diameter driven into the frozen sand with a hammer; the upper 8 cm was frozen; the 9-12 cm layer was loose, dry sand; from 13-30 cm the sand was damp; >30 cm was wet sand.
3. Inner Beach - just above presumed water's edge. One sample taken with conduit pipe as in #2. The upper 5 cm was frozen, and >6 cm the sand was wet. Total core's length, 15 cm.

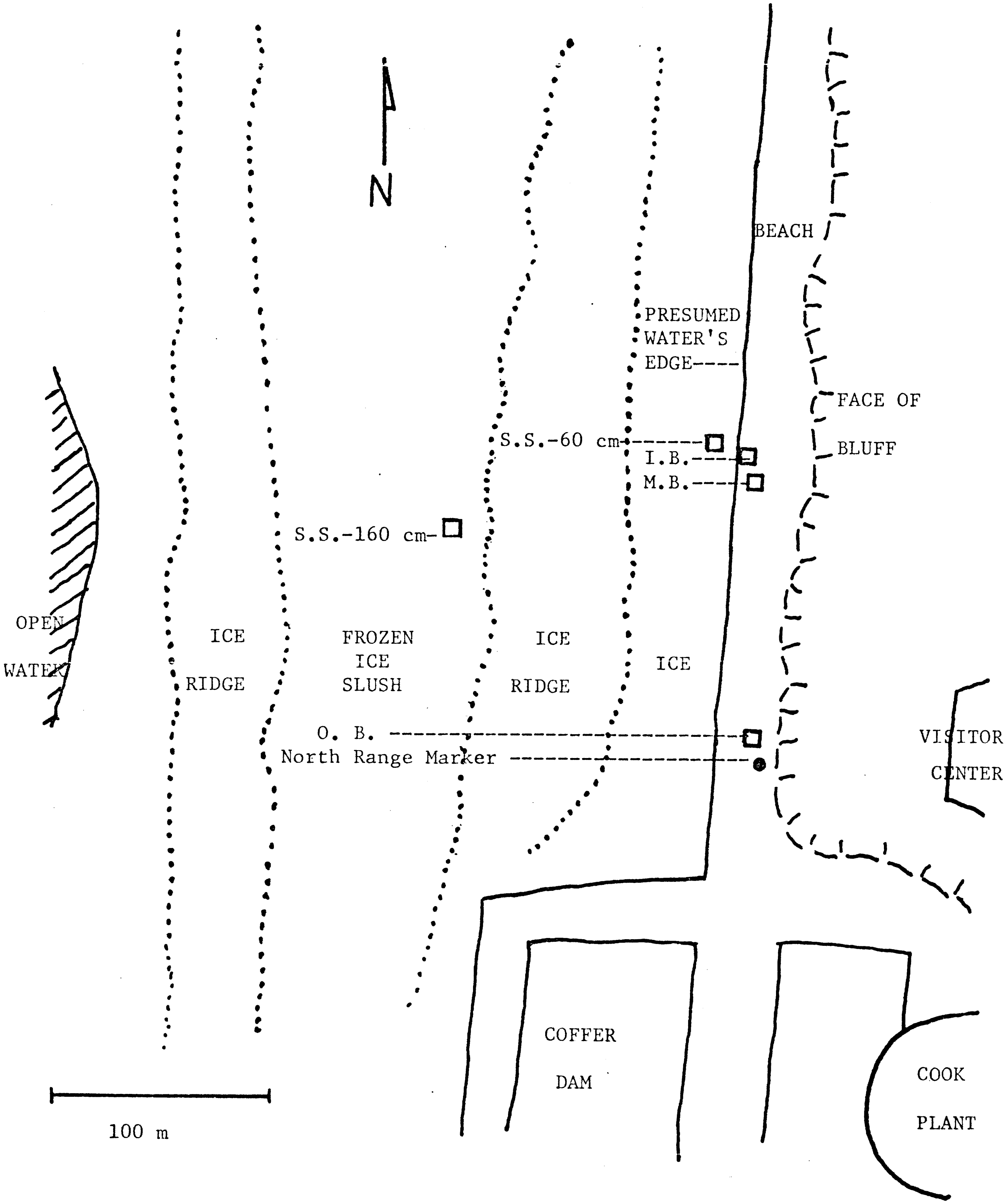

Figure 3. Sketch of psammon sampling sites. D. C. Cook Plant. January 31, 1972.

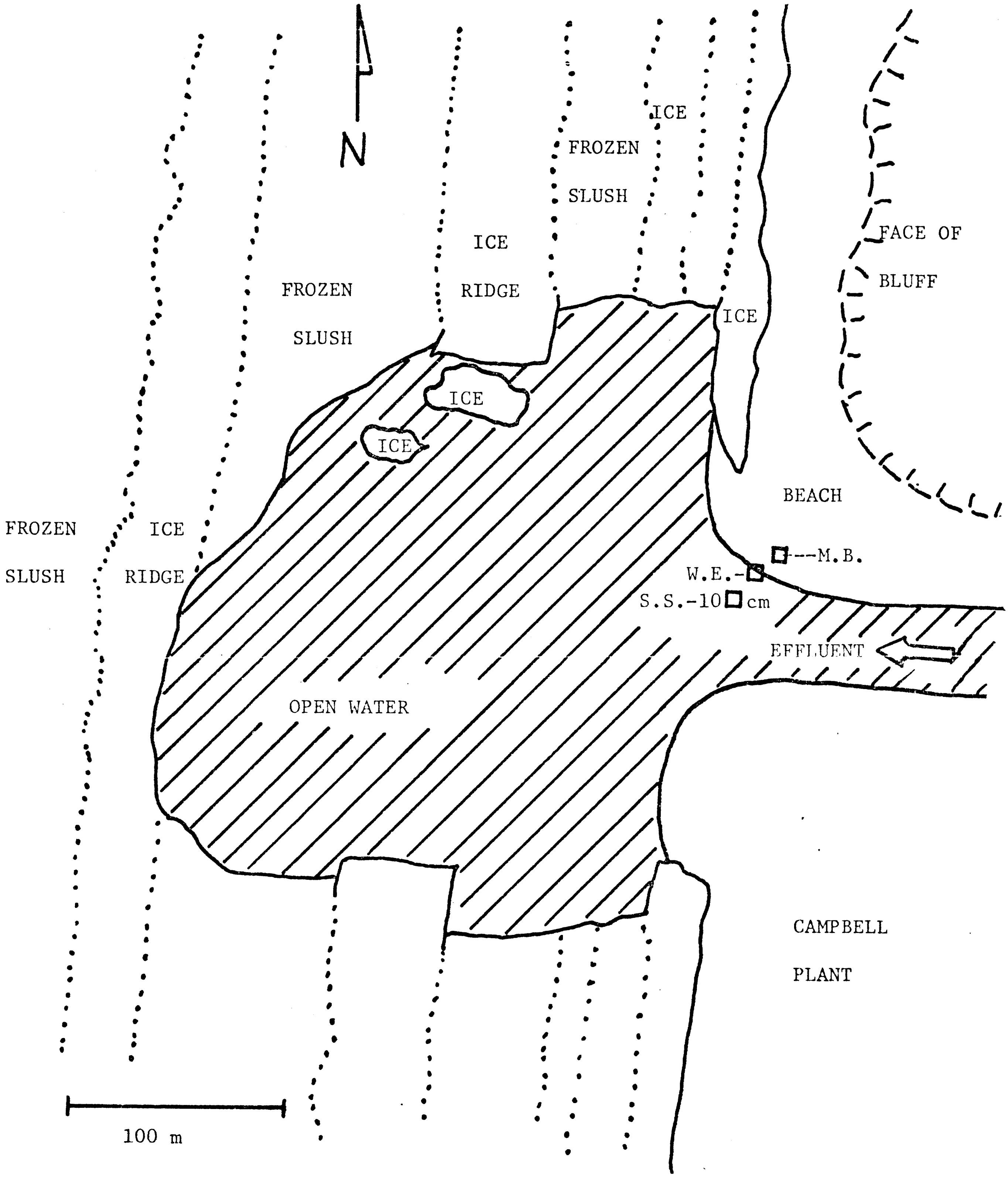

Figure 4. Sketch of psammon sampling sites. Campbell Plant. February 1, 1972.

4. Submerged Sand - 60 cm--a hole was chopped in a thin layer of ice over an air pocket, then an ice auger was used to bore through 30 cm of ice to 30 cm of ice-slush and water beneath. Two cores 7 cm in diameter and 1 core 5 cm in diameter were extracted. In addition, 5 samples were taken with an Hayward "orange peel" grab after the cores had been removed. The grab samples were held in a galvanized tub outdoors (air temperature ca. -3°C) until the macrofauna could be extracted.

5. Submerged Sand - 160 cm--a hole through 15 cm of refrozen ice slush was drilled with an ice auger and the orange peel grab was used to take 5 samples. The samples were held in a tub as above.

CAMPBELL PLANT

1. Middle Beach - frozen sand to at least 15 cm. This was sampled with a 4.8 cm conduit pipe as described for sites 2. and 3. at the Cook Plant.

2. Water's Edge - a 5 cm diameter plastic corer was pushed into sand beneath about 1 cm of water to a depth of 15 cm.

3. Submerged Sand - 10 cm--a 5-cm diameter plastic corer was pushed into sand beneath about 10 cm of water to a depth of 15 cm.

Four separate procedures were used to extract the organisms from the sand. The upper few centimeters from several samples were removed as they were extruded from the corer tubes and subjected to slow percolation with salt water. Ice made from tap water with 1-1.5% NaCl by weight was crushed and placed over these sample portions in a 5-cm diameter plastic tube. The salty ice was separated from the sand by a cotton pad 1 cm thick in each case. The lower ends of the tubes were covered with 0.15 mm-mesh plankton netting (#10) to retain non-living materials and immersed in dishes of Lake Michigan water. As the salty ice melted, saltwater percolated through the sand and into the dish below. Presumably, the osmotic stress of the salt would drive the mobile animals out into the dish below for examination. This procedure is time-consuming, especially in the search of the dishes for living animals, but has the advantage of yielding ciliate Protozoa in good condition. This was confirmed by previous extractions of stream-bank samples.

The second procedure was designed to yield a purified sample of diatom tests from the surfaces of the submerged sand samples. It is described in the special section on diatoms.

The last two procedures were essentially qualitative ones. Smaller or larger samples of sand were swirled with tap water in a container, and the lighter detritus and animals were decanted off in the water through finer or coarser netting. Small samples (cores) were decanted through a #28-mesh phytoplankton net (mesh openings about 0.06 mm wide), and large samples (grab samples) were decanted through a #10-mesh net (0.15 mm openings) for larger microfauna and macrofauna. Samples were examined without preservation.

Results of the surveys: the animals found in the various samples and sample portions are listed in Table 4. The samples are represented by a code related to the sampling locations: OB= outer beach; MB = middle beach; IB = inner beach; WE = water's edge; SS = submerged sand; DEC = decanted through (with # of mesh seze of netting used). It is clear that the numbers of animals were uniformly low. Although some forms were "abundant" in the orange peel grab samples, this is a relative rather than an absolute measure. Quantitative abundance estimates will require more methodological controls. Some animals listed are not genuine psammo-littoral forms, but wandered in from the overlying water. These are Cladocera and "Other Copepoda". The Chironomidae larvae were both found in shallow samples (4-8 m) of the regular benthos survey: *Paracladopelma* cfr. *galaptera* and *Parachironomus* cfr. *demeijerei*. The abundant Ciliata in the Campbell Plant sample WE-1 possibly developed in the unpreserved sample after it was taken. Such concentrations may or may not occur under natural conditions.

The exploratory nature of these samples precludes thorough discussion of the actual results. In general, however, it is clear that psammo-littoral organisms do occur in the beaches near the Cook Plant in winter, although in very low numbers.

Further work on extraction procedures is probably necessary, and in fact is continuing, to determine how thoroughly the animals can be extracted. These samples must be considered unreliable for quantitative estimates until such work is completed.

Winter samples are expected to be low in faunal abundance. It is noteworthy here, however, that the densities of organisms in the present samples are far below those for samples reported by Pennak (1940)[1] from lake beaches in Wisconsin. Pennak (loc. cit.) sampled in both Lakes Michigan and Superior, and found psammo-littoral fauna to be relatively and absolutely rare.

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[1] Pennak, R. W. 1940. Ecology of the macroscopic Metazoa inhabiting the sand beaches of some Wisconsin Lakes. Ecol. Monogr. 10:537-615.

TABLE 4. Psammon animals.

Sample	Fraction	Extraction Method	Cladocera	Harpacticoidae	Other Copepoda	Chironomidae	Ceratopogonidae	Other Insecta	Protozoa (Ciliata)	Turbellaria	Nematoda	Rotifera	Naididae	Aelosoma	Sampling Device
						COOK PLANT									
OB-1	surface	salty ice	no animals												5 cm corer
	lower part	DEC-28	no animals												
OB-2	total	DEC-28	-	2	1	-	-	1	-	2	1	-	1	1	7 cm corer
OB-3	total	DEC-28	-	-	1	-	-	-	-	-	1	-	1	-	7 cm corer
MB-1	surface	salty ice	no animals												3.8 cm corer
	lower part	DEC-28	no animals												
IB-1	total	DEC-28	-	-	-	-	-	-	-	-	1	-	1?	-	3.8 cm corer
SS-60-1	water	DEC-28	-	-	1	-	-	-	-	-	-	-	-	-	5 cm corer
	surface	salty ice	no animals												
	lower part	DEC-28	-	-	-	1	-	-	-	-	-	-	-	-	
SS-60-2	water	DEC-28	-	-	4	-	-	-	1+	-	-	-	-	-	7 cm corer
	total sand	DEC-28	-	1	-	-	-	-	-	2	-	-	-	-	
SS-60-3	total	DEC-28	1	-	4	2	-	-	-	-	-	-	-	1	7 cm corer
SS-60-4	total	DEC-10	rare	rare	abund.	comm.	-	-	-	comm.	-	-	very rare	-	5 orange peel grabs
SS-160-1	total	DEC-10	-	-	rare	very abund.	rare	-	-	very abund.	-	-	-	-	5 orange peel grabs
						CAMPBELL PLANT									
MB-1	total	DEC-28	no animals												3.8 cm corer
WE-1	water	whole	-	-	-	-	-	-	very abund.	-	-	-	-	-	5 cm corer
	surface	salty ice	-	-	-	-	-	-	-	-	-	3	-	-	5 cm corer
	lower part	DEC-28	-	-	-	2	-	-	-	-	-	2	1	-	5 cm corer
SS-10-1	water	DEC-28	-	-	1	-	-	-	-	-	-	-	-	-	5 cm corer
	surface	salty ice	no animals												5 cm corer
	lower part	DEC-28	-	-	-	-	-	-	-	7	-	1	-	-	5 cm corer

The ice-free and warmed condition of the psammo-littoral environment near the Campbell Plant did not seem to support a drastically different interstitial fauna. Of course, Rotifera were observed only in Campbell Plant samples in this series. The significance of the difference is uncertain in the absence of more extensive samples and reliable extraction techniques.

Psammon--Diatom Extraction and Cleaning

A submerged sand core was extruded and the upper few centimeters were placed in a 1000 ml beaker. The sample was then treated to clean the diatom frustules and to facilitate the separation of the frustules from the sand.

Thirty per cent H_2O_2, sufficient to cover the sample by about one cm, was added, and the sample was allowed to sit for several minutes. Small amounts of $K_2Cr_2O_7$ were carefully added until a noticeable reaction started. Upon completion of the reaction, the cleaned diatom frustules were removed by diluting the sample with about 400 ml distilled H_2O, mixing and decanting to two 250 ml beakers where the diatom frustules were allowed to settle out for about 24 hours.

After settling, most of the liquid was decanted from the 250 ml beakers. The original sample was again washed with about 400 ml distilled H_2O and then decanted into the 250 ml beakers where the frustules were allowed to settle out.

This process was repeated once again to assure that most of the diatom frustules were removed from the original sample.

The concentrated diatom frustules were transferred to storage bottles. Slides were prepared by withdrawing subsamples from the storage bottles and mounting the frustules in Hyrax mounting medium. Qualitative determinations were made using a compound microscope and magnifications of 500x and 1000x.

Table 5 is a species list for each area, Cook Plant and Campbell Plant.

TABLE 5. Psammon diatom species list.

COOK PLANT, January 31, 1972

Achnanthes clevei Grun.
Achnanthes clevie v. *rostrata* Hust.
Achnanthes conspicua A. Mayer
Achnanthes lanceolata (Bréb.) Grun.
Achnanthes lanceolata v. *dubia* Grun.
Achnanthes lanceolata v. *eliptica* Cleve
Achnanthes pinnata Hust.
Amphora ovalis v. *pediculus* (Kütz.) V.H.
Amphora rotunda Skv.
Anomoeoneis vitrea (Grun.) Ross
Asterionella formosa Hassall
Caloneis bacillum v. *lancettula* (Schulz) Hust.
Caloneis ventricosa var.?
Caloneis ventricosa truncatula (Grun.) Meist.
Cocconeis diminuta Pant.
Cocconeis disculus Schum.
Cocconeis placentula v.*euglypta* (Ehr.) Cleve
Cyclotella comta (Ehr.) Kütz.
Cyclotella menighiniana v. *plana* Fricke
Cyclotella michiganiana Skv.
Cyclotella stelligera (Cleve et Grun.) V.H.
Cymbella microcephala Grun.
Cymbella parva (Wm. Smith) Cleve
Denticula tenuis v. *crassula* (Naeg.) Hust.
Diatoma tenue v. *elongatum* Lyngb.
Diatoma vulgare Bory.
Diploneis boldtiana Cleve
Fragilaria capucina Desm.
Fragilaria crotonensis Kitton
Fragilaria intermedia Grun.
Fragilaria pinnata Ehr.
Gyrosigma acuminatum (Kütz.) Rabh.
Melosira granulata (Ehr.) Ralfs
Melosira islandica O.Müll
Melosira italica v. *valiva* Grun.
Navicula acceptata Hust.
Navicula capitata Ehr.
Navicula capitata v. *hungarica* (Grun.) Ross
Navicula clememtis Grun.
Navicula clementis v. *quadristigmata* Mang.
Navicula cryptocephala v. *veneta* (Kütz.) Rabh.
Navicula decussis Østr.

TABLE 5 continued---

Navicula lanceolata (Ag.) Kütz.
Navicula latens Krasske
Navicula menisculus Schum.
Navicula menisculus v. *upsaliensis* Grun.
Navicula micropupula Choln.
Navicula mutata Krasske
Navicula paludosa Hust.
Navicula platystoma v. *pantocsekii* Wisl. et Kolbe
Navicula radiosa v. *tenella* (Bréb. ex Kütz.) Grun.
Navicula seminuloides Hust.
Navicula scutalloides W. Sm. ex Greg.
Navicula stroesei A. Cleve
Navicula tripunctata (O. F. Müll.) Bory.
Navicula viridula (Kütz.) Kütz. emend.V.H.
Navicula sp.
Navicual sp.
Navicula sp.
Neidium dubium (Ehr.) Cleve
Neidium sp. (our #3)
Nitzschia amphibia Grun.
Nitzschia angustata (Wm. Smith) Grun.
Nitzschia confinis Hust.
Nitzschia dissipata v. *media* (Hantz.) Grun.
Nitzschia fonticola Grun.
Nitzschia kutzingiana Hilse
Nitzschia recta Hantz.
Nitzschia sp. (our #2)
Opephora ansata Hohn & Hellerm.
Opephora martyi Herib
Oestrupia zachariasi (Reich.) comb. nov.
Rhizosolenia eriensis H. L. Smith
Rhizosolenia gracilis H. L. Smith
Stephanodiscus alpinus Hust. ex Huber-Pestalozzi
Staphanodiscus hantzschii Grun.
Stephanodiscus minutus Grun.
Stephanodiscus niagare Shr.
Stephanodiscus subtilis (Van Goor) A. Cleve
Stephanodiscus tenuis Hust.
Stephanodiscus transilvanicus Pant.
Surirella angustata Kütz.
Synedra filiformis Grun.
Synedra ostenfeldi (Krieger) A. Cleve
Synedra ulna (Nitz.) Ehr.
Tabellaria fenestrata (Lyngb.) Kütz.

TABLE 5 continued---

CAMPBELL PLANT, January 31, 1972

Achnanthes affinis Grun.
Achnanthes austrica v. *helvetica* Hust.
Achnanthes clevei Grun.
Achnanthes clevei v. *rostrata* Hust.
Achnanthes conspicua A. Mayer
Achnanthes exigua Grun.
Achnanthes hungarica Grun.
Achnanthes lanceolata (Bréb.) Grun.
Achnanthes lanceolata v. *dubia* Grun.
Achnanthes lanceolata v. *omissa* Reim.
Achnanthes lanceolata v. *robusta* Hust.
Achnanthes lauenburgiana Hust.
Achnanthes lemmermanni Hust.
Achnanthes linearis (Wm. Smith) Grun.
Achnanthes minutissima Kütz.
Achnanthes minutissima v. *cryptocephala* Grun.
Amphora calumetica (Thomas) Per.
Amphora ovalis v. *gracilis* (Ehr.) V.H.
Amphora ovalis v. *libyca* (Ehr.) Cleve.
Amphora ovalis pediculis (Kütz.) V.H.
Amphora rotunda Skv.
Amphora sibirica Skv.
Amphora sp.(*Amphora neglecta* Stoermer in press)
Asterionella formosa Hassall
Caloneis ventricosa v. *minuta* (Grun.) Patr.
Cocconeis diminuta Pant.
Cocconeis disculus Schum.
Cocconeis pediculis Ehr.
Cocconeis placentula Ehr.
Cocconeis placentula v. *euglypta* (Ehr.) Cleve
Cocconeis placentula v. *lineata* (Ehr.) V.H.
Cocconeis thumensis A. Mayer
Cocconeis sp. (our #2)
Coscinodiscus subsalsa Juhl.-Dannf.
Cyclotella atomus Hust.
Cyclotella comta (Ehr.) Kütz.
Cyclotella cryptica Reimann, Lewin, & Guillard
Cyclotella meneghiniana Kütz.
Cyclotella meneghiniana fo. *plana* Frieke
Cyclotella michiganiana Skv.
Cyclotella ocellata Pant.
Cyclotella stelligera (Cleve. et Grun.) V.H.
Cyclotella temperei Per. & Hérib.

TABLE 5 continued---

Cymbella affinis Kütz.
Diatoma tunue v. *elongatum* Lyngb.
Diatoma vulgare Bory
Epithemia turgida (Ehr.) Kütz.
Eucocconeis flexella v. *alpestris* Brun.
Fragilaria construens (Ehr.) Grun.
Fragilaria construens v. *capitata* Hérib.
Fragilaria crotonensis Kitton
Fragilaria pinnata Ehr.
Gomphonema acuminatum Ehr.
Gomphonema constrictum Ehr.
Gomphonema intricatum Kütz.
Gomphonema olivaceum (Lyngb.) Kütz.
Melosira granulata (Ehr.) Ralfs.
Melosira granulata v. *angustissima* O. Müll.
Melosira islandica O. Müll.
Melosira italica (Ehr.) Kütz.
Navicula anglica Ralfs.
Navicula aurora Soo.
Navicula bacillum Ehr.
Navicula biridula v. *linearis* Hust.
Navicula capitata Ehr.
Navicula costulata Grun.
Navicula cryptocephala Kütz.
Navicula cryptocephala v. *intermedia* Grun.
Navicula decussis Østr.
Navicula diluviana Hust.
Navicula integra (Wm. Smith) Ralfs.
Navicula latens Krasske
Navicula lacustris Greg.
Navicula memisculus v. *upsaliensis* Grun.
Navicula minima Grun.
Navicula mutata Krasske
Navicula paludosa Hust.
Navicula pupula Kütz.
Navicula pupula v. *rectangularis* (Greg.) Grun.
Navicula reinhardtii Grun.
Navicula seminuloides Hust.
Navicula subprocera Hust.
Navicula tantula Hust.
Navicula tripunctata (O. F. Müll.) Bory.
Navicula tuscula v. *obtusa* A. Cleve
Navicula tuscula fo. *rostrata* Hust.
Navicula vanheurckii Patr.
Navicula ventralis Hust.
Navicula viridula Kütz.

TABLE 5 continued---

Navicula sp.
Navicula sp. (our. #45)
Navicula sp. (our #70)
Nedium bisulcatum v. *baicalensis* (Skv. & Meyer) Reim.
Nedium dubium (Ehr.) Cleve.
Nitzschia acuta Hantz.
Nitzschia amphibia Grun.
Nitzschia dissipata (Kütz.) Grun.
Nitzschia fonticola Grun.
Nitzschia kutzingiana Hilse
Nitzschia palea (Kütz.) Wm. Smith
Nitzschia romana Grun.
Nitzschia thermalis v. *angustissima* O. Müll.
Pinnularia borealis Ehr.
Rhizosolenia eriensis H. L. Smith
Stephanodiscus hantzschii Grun.
Stephanodiscus minutus Grun.
Stephanodiscus niagare Ehr.
Stephanodiscus subtilis (Van Goor) A. Cleve.
Stephanodiscus tenuis Hust.
Surirella angustata Kütz.
Synedra minuscula Grun.
Synedra pulchella Ralfs.
Synedra ulna (Nitz.) Ehr.
Tubellaria fenestrata (Lyngb.) Kütz.

A.8 Study of the Local Fishes

Studies of the fishes of the Cook Plant area will be begun in 1972. Efforts have been and are being made to obtain a qualified fishery biologist to supervise these studies. To date no one has been found, but the search will continue.

The initial program of fish studies will include the fabrication of an air-lift fish-egg sucker for use in attempts to ascertain whether the plant area is used as a spawning ground. Plankton nets will be used in efforts to catch juvenile fish.

Also included will be: 1) obtaining a collector's license for John C. Ayers or his substitute; 2) purchase and use of a beach seine, a shrimpers' try-trawl, and some gill-nets; and 3) purchase and use of gear for the making of standard measurements.

Beach seining, trawling, and gill-netting to cover both day and night will be carried out on a monthly basis during the ice-free season, with a probable late start in 1972 if supply-time on the nets is appreciable.

At present there is sufficient expertise within the Great Lakes Research Division and Cook Plant personnel to fish the gear listed above and to make standard measurements. It is therefore planned to preserve all fish caught for later identification, age determination, and determination of gonadal condition at such time as a qualified fishery biologist can be added to our staff.

Present plans are for plant-site collections and for collections from a control region seven miles south of the plant site.

A.9 Support of Aerial Scanning

During the spring of 1971 the Infrared and Optics Labroatory of the University of Michigan's Willow Run Laboratories made several overflights of the southern Lake Michigan shoreline. Included in these were the area of the Cook Plant and the mouth of the St. Joseph River. Each of the overflights included color photography, infrared imagery, and multispectral imagery of the Cook Plant area and the river mouth. As a part of the "ground truth" team operating under these overflights, our assignment was to carry out westward runs from the mouth of the St. Joseph River measuring surface water temperature, water color, and water transparency across the thermal bar (4^oC); also in connection with the overflights, we carried out phytoplankton analyses of water samples collected off the Campbell Plant of Consumers Power Company at Port Sheldon, Michigan, by the Consumers ground truth team there.

Westward ground truth runs from the St. Joseph River mouth were carried out on 22, 23, 30 April, 7 May, and 9 June (although on the last date the scheduled overflight was not made). All these runs were made from the Indiana and Michigan Electric Company's cruiser DONALD C. COOK, by captain Jon Barnes. Each run began with a stop for measurements at the pierheads of the river, after which surface water temperatures were recorded underway at one minute intervals with stops at each five minutes for sextant fixes and measurements of water color and transparency. The station stops are shown numbered serially outward from the pierheads (pierheads were Station 0) in Figure 5 and Figure 6. In each of these figures the position of the 4^oC isotherm is also shown. No plot of the run of 9 June is given because there was no overflight.

The complete data from the westward runs from the river mouth are given in Table 6. The identifications and counts of the phytoplankton samples collected at Consumers Campbell Plant are given in Tables 7 through 13.

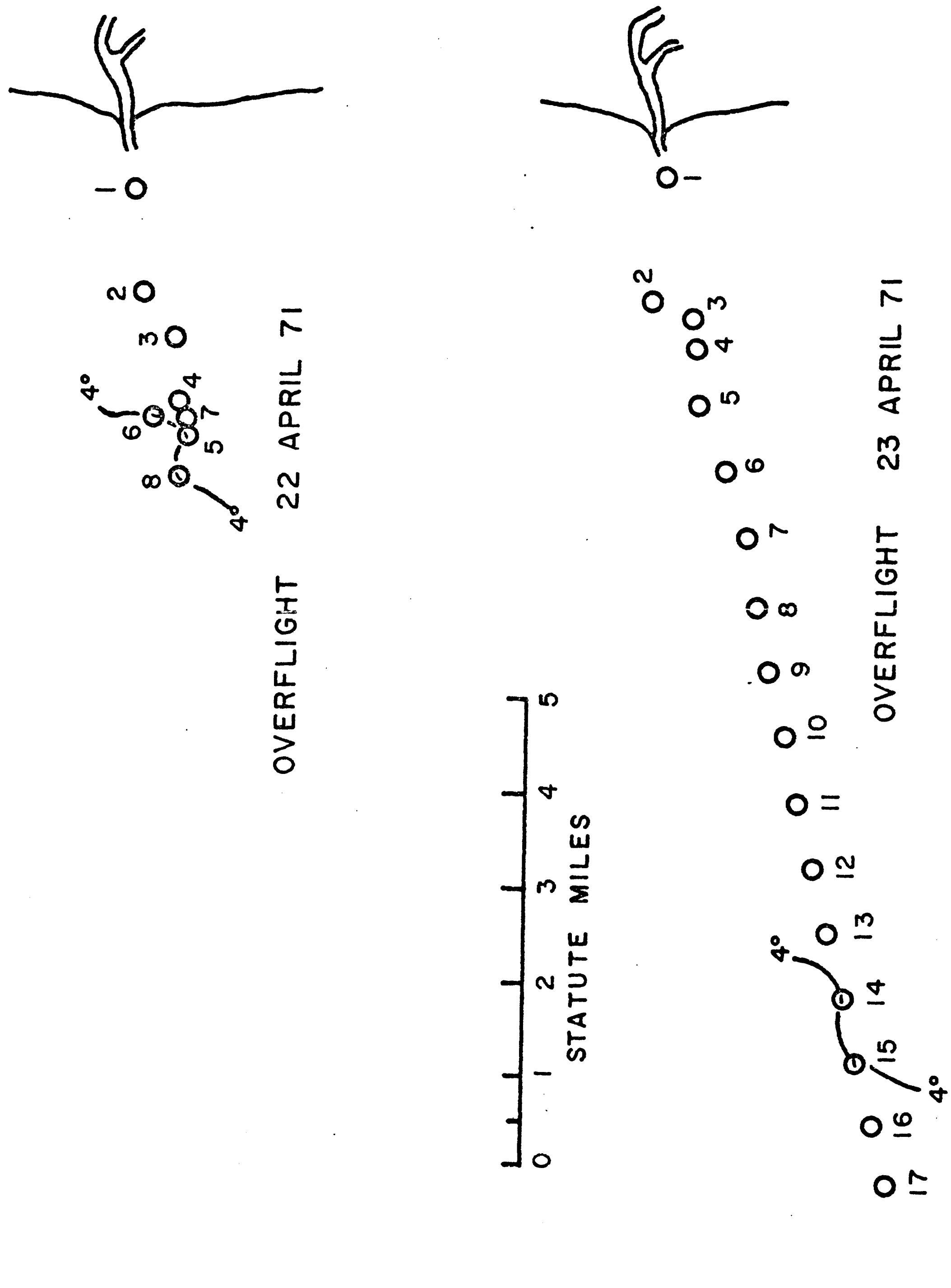

FIGURE 5. Station locations of "Ground truth" observations for Willow Run overflights, 1971.

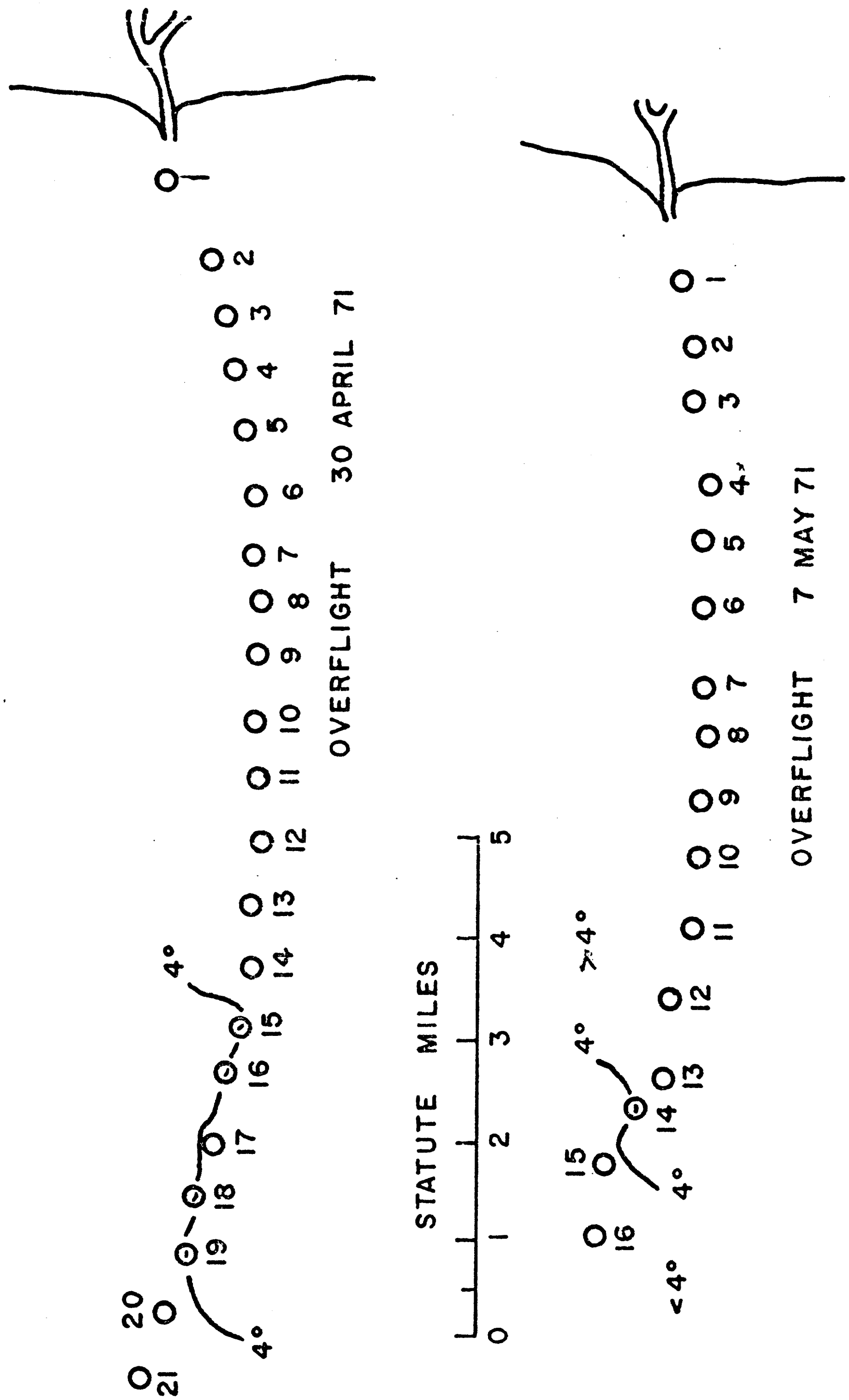

FIGURE 6. Station locations of "Ground truth" observations for Willow Run overflights, 1971.

TABLE 6. Ground Truth data, Willow Run Overflights, St. Joseph River. Spring/Summer 1971.

Location	Time	Temperature		Secchi Transparency	Water color
		22 April 1971 Wind N-NE 15-20 mph Swells 3-5 ft			
Pierheads	0812	13.0°C	55.4°F	0.8 m	brown
	0813	13.0	55.4		
	0814	13.0	55.4		
	0815	12.3	54.1		
	0816	6.0	42.8		
	0817	5.8	42.4		
	0818	5.9	42.6		
	0819	6.0	42.8		
100 yds. west of piers	0820	11.8	53.2	0.6	sandy
	0821	11.0	51.8		
	0822	5.5	41.9		
	0823	5.9	42.6		
	0824	6.0	42.8		
	0825	6.0	42.8		
	0826	6.1	43.0		
	0827	6.0	42.8		
	0828	6.0	42.8		
	0829	6.0	42.8		
Station 1	0830	6.0	42.8	1.2	light sandy brown
	0831	6.0	42.8		
	0832	6.0	42.8		
	0833	6.0	42.8		
	0834	6.0	42.8		
	0835	6.0	42.8		
	0836	6.0	42.8		
	0837	6.0	42.8		
	0838	6.5	43.7		
	0839	6.0	42.8		
Station 2	0840	6.0	42.8	1.4	light sandy brown
	0841	6.0	42.8		
	0842	6.0	42.8		
	0843	6.0	42.8		
	0844	6.1	43.0		
	0845	6.0	42.8		
	0846	6.0	42.8		
	0847	6.0	42.8		
	0848	5.8	42.4		
	0849	6.0	42.8		

--continued

TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 3	0850	6.0°C	42.8°F	0.8 m	light sandy brown
	0851	6.0	42.8		
	0852	6.0	42.8		
	0853	6.0	42.8		
	0854	6.0	42.8		
	0855	5.5	41.9		
	0856	5.5	41.9		
	0857	6.0	42.8		
	0858	6.0	42.8		
	0859	6.0	42.8		
	0900	5.8	42.4		
Station 4	0901	5.0	41.0	1.9	milky or sandy light brown
	0902	5.2	41.4		
	0903	5.9	42.6		
	0904	5.5	41.9		
	0905	5.5	41.9		
	0906	5.5	41.9		
	0907	5.0	41.0		
	0908	5.0	41.0		
	0910	5.2	41.4		
	0911	5.5	41.9		
	0912	5.3	41.5		
	0913	5.2	41.4		
	0914	5.0	41.0		
Station 5	0915	5.0	41.0	2.3	milky light brown green
	0916	4.8	40.6		
	0917	4.8	40.6		
	0918	4.9	40.8		
	0919	4.5	40.1		
	0920	4.0	39.2		
	0921	4.0	39.2		
Station 6	0922	4.0	39.2	2.2	milky brown green
	0923	4.2	39.6		
	0924	4.0	39.2		
	0925	4.5	40.1		
	0926	4.0	39.2		
	0927	4.0	39.2		
	0928	4.0	39.2		
	0929	4.0	39.2		

--continued

TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 7	0930	3.8°C	38.8°F	2.8	milky light green
	0931	3.9	39.0		
	0932	4.0	39.2		
	0933	4.0	39.2		
	0934	3.9	39.0		
	0935	3.9	39.0		
	0936	3.5	38.3		
	0937	4.0	39.2		
	0938	4.0	39.2		
	0939	4.0	39.2		
	0940	4.0	39.2		
	0941	4.0	39.2		
Station 8	0942	4.0	39.2	2.8	milky light green
	0943	4.0	39.2		
	0944	4.0	39.2		

RETURNED TO BENTON HARBOR

23 April 1971
Wind SW-W 6 mph.
Swell 1 ft. from NW

Location	Time	Temperature		Secchi Transparency	Water color
Pierheads	0812	14.0	57.2	0.8 m	dark brown
	0813	14.0	57.2		
	0814	14.0	57.2		
	0815	14.0	57.2		
	0816	7.5	45.5		
Station 1	0817	7.5	45.5	0.8	milky light brown
	0818	7.5	45.5		
	0819	7.0	44.6		
	0820	7.0	44.6		
	0821	7.0	44.6		
	0822	7.5	45.5		
	0823	7.0	44.6		
	0824	7.0	44.6		
	0825	7.0	44.6		
	0826	6.9	44.4		
	0827	7.0	44.6		
	0828	7.0	44.6		
	0829	6.5	43.7		
	0830	6.2	43.2		
	0831	6.0	42.8		

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TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 2	0832	6.0°C	42.8°F	1.5 m	milky light brown
	0833	6.1	43.0		
	0834	6.2	43.2		
	0835	6.0	42.8		
	0836	6.0	42.8		
	0837	6.0	42.8		
	0838	6.0	42.8		
	0839	6.1	43.0		
	0840	6.2	43.2		
Station 3	0841	6.1	43.0	1.8	milky brown green
	0842	6.1	43.0		
	0843	6.1	43.0		
	0844	6.1	43.0		
	0845	6.0	42.8		
	0846	6.1	43.0		
	0847	6.0	42.8		
	0848	6.1	43.0		
	0849	6.3	43.3		
	0850	6.2	43.2		
	0851	6.3	43.3		
Station 4	0852	6.4	43.5	1.9	milky brown green
	0853	6.3	43.3		
	0854	6.5	43.7		
	0855	6.5	43.7		
	0856	6.5	43.7		
	0857	6.5	43.7		
	0858	6.7	44.1		
	0859	6.5	43.7		
	0900	6.5	43.7		
Station 5	0901	6.0	42.8	2.1	milky brown green
	0902	6.3	43.3		
	0903	6.3	43.3		
	0904	6.2	43.2		
	0905	6.2	43.2		
	0906	6.3	43.3		
	0907	5.9	42.6		
	0908	5.9	42.6		
	0909	5.9	42.6		
	0910	5.9	42.6		
	0911	5.7	42.3		

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TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 6	0912	5.7°C	42.3°F	2.3 m	milky brown green
	0913	5.7	42.3		
	0914	5.6	42.1		
	0915	5.8	42.4		
	0916	5.8	42.4		
	0917	5.7	42.3		
	0918	5.9	42.6		
	0919	5.8	42.4		
	0920	5.9	42.6		
	0921				
	0922				
	0923				
	0924				
	0925				
	0926				
	0927				
	0928	5.8	42.4		
	0929	5.8	42.4		
	0930	6.0	42.8		
	0931	6.0	42.8		
	0932	5.9	42.6		
	0933	5.9	42.6		
	0934	5.9	42.6		
	0935	5.5	41.9		
	0936	5.6	42.1		
	0937	5.5	41.9		
	0938	5.5	41.9		
Station 7	0939	5.5	41.9	2.9 m	milky brown green
	0940	5.5	41.9		
	0941	5.5	41.9		
	0942	5.6	42.1		
	0943	5.7	42.3		
	0944	5.9	42.6		
	0945	5.9	42.6		
	0946	5.9	42.6		
Station 8	0947	5.7	42.3	2.9	milky brown green
	0948	5.9	42.6		
	0949	5.9	42.6		
	0950	5.9	42.6		
	0951	5.9	42.6		
	0952	6.1	43.0		
	0953	6.2	43.2		

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TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 9	0954	6.2°C	43.2°C	2.5 m	milky brown green
	0955	6.1	43.0		
	0956	6.3	43.3		
	0957	6.3	43.3		
	0958	6.5	43.7		
	0959	6.5	43.7		
	1000	6.5	43.7		
Station 10	1001	6.3	43.3	2.5	milky brown green
	1002	6.2	43.2		
	1003	6.2	43.2		
	1004	6.2	43.2		
	1005	6.1	43.0		
	1006	6.1	43.0		
	1007	6.0	42.8		
Station 11	1008	5.9	42.6	2.5	milky brown green
	1009	5.9	42.6		
	1010	5.0	41.0		
	1011	4.5	40.1		
	1012	4.3	39.7		
	1013	4.2	39.6		
	1014	4.6	40.3		
Station 12	1015	4.6	40.3	5.6	milky light green
	1016	4.5	40.1		
	1017	4.5	40.1		
	1018	4.7	40.5		
	1019	4.4	39.9		
	1020	4.3	39.7		
	1021	4.5	40.1		
Station 13	1022	4.3	39.7	3.7	milky light green
	1023	4.4	39.9		
	1024	4.3	39.7		
	1025	4.2	39.6		
	1026	4.1	39.4		
	1027	4.0	39.2		
	1028	4.0	39.2		
Station 14	1029	4.0	39.2	3.7	milky light green
	1030	4.0	39.2		
	1031	4.1	39.4		
	1032	4.0	39.2		
	1033	4.0	39.2		
	1034	4.0	39.2		

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TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 15	1035	4.0°C	39.2°F	3.8 m	milky light green
	1036	4.0	39.2		
	1037	4.0	39.2		
	1038	4.0	39.2		
	1039	4.0	39.2		
	1040	4.0	39.2		
	1041	4.0	39.2		
	1042	4.0	39.2		
Station 16	1043	3.9	39.0	4.1	milky light green
	1044	3.8	38.8		
	1045	4.0	39.2		
	1046	3.9	39.0		
	1047	3.9	39.0		
	1048	3.9	39.0		
	1049	3.9	39.0		
	1050	4.0	39.2		
Station 17	1051	3.8	38.8	4.1	milky light green
RETURNED TO BENTON HARBOR					
		30 April 1971 Wind SW-W 0-5 mph Swells 6"-1'			
Boat basin	0750	11.5	52.7		
Pierheads	0758	11.8	53.2	0.8	Dark brown (river water)
	0801	11.8	53.2		
	0802	11.2	52.2		
	0803	11.2	52.2		
	0804	10.8	51.4		
Station 1	0805	10.5	50.9	0.9	Dark brown (outer edge of plume)
	0811	10.2	50.4		
	0812	10.2	50.4		
	0813	7.0	44.6		
	0814	7.0	44.6		

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TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 2	0815	6.9°C	44.4°F	2.2 m	Slightly milky slightly brownish light green
	0819	6.9	44.4		
	0820	6.9	44.4		
	0821	6.9	44.4		
	0822	6.9	44.4		
Station 3	0823	6.8	44.2	2.5	
	0828	6.8	44.2		
	0829	6.8	44.2		
	0830	6.8	44.2		
	0831	6.6	43.9		
Station 4	0832	6.7	44.1	2.5	Slightly milky slightly brownish light green
	0836	6.7	44.1		
	0837	6.7	44.1		
	0838	6.8	44.2		
	0839	6.8	44.2		
	0840	6.8	44.2		
Station 5	0841	6.8	44.2	2.6	Slightly milky very slightly brownish light green
	0845	6.8	44.2		
	0846	6.8	44.2		
	0847	6.8	44.2		
	0848	6.8	44.2		
Station 6	0849	6.8	44.2	2.8	Slightly milky very slightly brownish light green
	0853	6.8	44.2		
	0854	6.8	44.2		
	0855	6.8	44.2		
	0856	6.8	44.2		
Station 7	0857	6.8	44.2	3.1	Slightly milky light green
	0902	6.8	44.2		
	0903	6.8	44.2		
	0904	6.7	44.1		
	0905	6.7	44.1		
Station 8	0906	6.7	44.1	3.0	Slightly milky very slightly brownish light green
	0911	6.7	44.1		
	0912	6.7	44.1		
	0913	6.5	43.7		
	0914	6.5	43.7		

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TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 9	0915	6.5°C	43.7°F	3.3 m	Slightly milky light green
	0918	6.2	43.2		
	0919	6.2	43.2		
	0920	6.2	43.2		
	0921	6.2	43.2		
Station 10	0922	6.2	43.2	4.0	Slightly milky light green
	0927	6.0	42.8		
	0928	5.8	42.4		
	0929	5.8	42.4		
	0930	5.8	42.4		
Station 11	0931	5.8	42.4	4.8	Slightly milky light green
	0935	5.6	42.1		
	0936	5.6	42.1		
	0937	5.2	41.4		
	0938	4.9	40.8		
Station 12	0939	4.6	40.3	6.5	Very slightly milky green
	0943	4.5	40.1		
	0944	4.4	39.9		
	0945	4.4	39.9		
	0946	4.3	39.7		
	0947	4.3	39.7		
Station 13	0948	4.2	39.5	6.7	Very slightly milky green
	0957	4.2	39.5		
	0958	4.2	39.5		
	0959	4.2	39.5		
	1000	4.2	39.5		
Station 14	1001	4.2	39.5	7.0	Very slightly milky green
	1007	4.2	39.5		
	1008	4.2	39.5		
	1009	4.1	39.3		
	1010	4.1	39.3		
	1011	4.0	39.2		
Station 15	1012	4.0	39.2	6.6	Very slightly milky green
	1016	4.0	39.2		
	1017	4.0	39.2		
	1018	4.0	39.2		
	1019	4.0	39.2		

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TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 16	1020	4.0°C	39.2°F	6.6 m	Very slightly milky green
	1027	4.0	39.2		
	1028	4.0	39.2		
	1029	4.0	39.2		
	1030	3.9	39.0		
	1031	3.9	39.0		
Station 17	1032	3.9	39.0	6.3	Very slightly milky green with patches of detritus
	1039	4.0	39.2		
	1040	4.0	39.2		
	1041	4.0	39.2		
	1042	4.0	39.2		
Station 18	1043	4.0	39.2	6.5	Very slightly milky green with detritus
	1052	4.0	39.2		
	1053	4.0	39.2		
	1054	4.0	39.2		
	1055	4.0	39.2		
Station 19	1056	4.0	39.2	6.5	Very slightly milky green with detritus
	1103	4.0	39.2		
	1104	4.0	39.2		
	1105	4.0	39.2		
	1106	3.9	39.0		
	1107	3.9	39.0		
Station 20	1108	3.9	39.0	6.3	Clear green with detritus
	1119	3.9	39.0		
	1120	3.9	39.0		
	1121	3.9	39.0		
	1122	3.9	39.0		
Station 21	1123	3.9	39.0	7.0	Clear green with detritus
RETURNED TO BENTON HARBOR					
		7 May 1971 Wind NE to E 10-15 mph			
Pierheads	0813	13.0	55.4	0.7	dark brown
	0814	13.0	55.4		
	0815	13.0	55.4		
	0816	12.0	53.6		
	0817	11.0	51.8		

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TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 1	0818	11.0°C	51.8°F	1.0 m	light brown
	0819	10.0	50.0		
	0820	10.0	50.0		
	0821	10.0	50.0		
	0822	10.0	50.0		
	0823	9.5	49.1		
	0824	9.2	48.6		
	0825	9.2	48.6		
	0826	9.0	48.2		
Station 2	0827	9.0	48.2	1.3	milky light brown
	0828	9.0	48.2		
	0829	9.0	48.2		
	0830	9.0	48.2		
	0831	9.0	48.2		
	0832	9.0	48.2		
	0833	9.0	48.2		
	0834	9.0	48.2		
	0835	9.0	48.2		
	0836	8.8	47.8		
	0837	8.5	47.3		
Station 3	0838	8.2	46.8	2.0	milky slightly brown light green
	0839	8.2	46.8		
	0840	8.1	46.6		
	0841	8.1	46.6		
	0842	8.2	46.8		
	0843	8.0	46.4		
	0844	8.0	46.4		
	0845	8.0	46.4		
	0846	8.0	46.4		
	0847	8.0	46.4		
	0848	8.0	46.4		
Station 4	0849	8.0	46.4	2.3	milky light brownish green
	0850	8.0	46.4		
	0851	8.0	46.4		
	0852	8.0	46.4		
	0853	8.0	46.4		
	0854	8.0	46.4		
	0855	8.0	46.4		
	0856	8.0	46.4		
	0857	8.0	46.4		
	0858	8.0	46.4		

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TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 5	0859	7.9°C	46.2°F	2.7 m	milky light green
	0900	7.7	45.9		
	0901	7.6	45.7		
	0902	7.5	45.5		
	0903	7.5	45.5		
	0904	7.5	45.5		
	0905	7.3	45.1		
	0906	7.3	45.1		
	0907	7.3	45.1		
	0908	7.3	45.1		
	0909	7.3	45.1		
Station 6	0910	7.2	45.0	3.8	milky light green
	0911	7.2	45.0		
	0912	7.2	45.0		
	0913	7.5	45.5		
	0914	7.5	45.5		
	0915	7.5	45.5		
	0916	7.5	45.5		
	0917	7.6	45.7		
	0918	7.7	45.9		
	0919	7.8	46.0		
Station 7	0920	7.8	46.0	3.9	milky light green
	0921	7.5	45.5		
	0922	7.5	45.5		
	0923	7.5	45.5		
	0924	7.7	45.9		
	0925	7.8	46.0		
	0926	7.8	46.0		
Station 8	0927	7.8	46.0	4.1	milky light green
	0928	7.9	46.2		
	0929	7.8	46.0		
	0930	7.9	46.2		
	0931	7.9	46.2		
	0932	7.9	46.2		
	0933	7.9	46.2		
	0934	7.9	46.2		
	0935	8.0	46.4		
Station 9	0936	8.0	46.4	4.0	milky light green
	0937	8.0	46.4		
	0938	8.0	46.4		
	0939	7.9	46.2		
	0940	8.0	46.4		
	0941	8.0	46.4		
	0942	8.0	46.4		
	0943	8.0	46.4		

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TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 10	0944	7.9°C	46.2°F	4.1 m	milky light green
	0945	7.9	46.2		
	0946	8.0	46.4		
	0947	7.9	46.2		
	0948	7.9	46.2		
	0949	7.9	46.2		
	0950	7.9	46.2		
	0951	7.9	46.2		
	0952	7.9	46.2		
Station 11	0953	7.4	45.3	4.4	milky light green
	0954	7.1	44.8		
	0955	7.2	45.0		
	0956	7.2	45.0		
	0957	7.2	45.0		
	0958	7.3	45.1		
	0959	7.3	45.1		
	1000	7.3	45.1		
	1001	7.2	45.0		
	1002	7.1	44.8		
	1003	7.0	44.6		
	1004	7.0	44.6		
Station 12	1005	7.0	44.6	4.5	milky light green
	1006	7.0	44.6		
	1007	6.8	44.2		
	1008	6.4	43.5		
	1009	6.0	42.8		
Station 13	1010	5.5	41.9	4.9	slightly milky light green
	1011	5.2	41.4		
	1012	5.2	41.4		
	1013	5.1	41.2		
	1014	5.2	41.4		
	1015	5.1	41.2		
	1016	5.0	41.0		
	1017	4.9	40.8		
	1018	4.9	40.8		
Station 14	1019	4.0	39.2	5.3	slightly milky light green
	1020	3.9	39.0		
	1021	4.0	39.2		
	1022	4.0	39.2		
	1023	4.0	39.2		
	1024	4.0	39.2		
	1025	4.0	39.2		
	1026	4.0	39.2		
	1027	4.0	39.2		
	1028	3.9	39.0		
	1029	3.8	38.8		

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TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 15	1030	3.9°C	39.0°F	6.0 m	Clear light green
	1031	3.9	39.0		
	1032	3.9	39.0		
	1033	3.8	38.8		
	1034	3.9	39.0		
	1035	3.8	38.8		
	1036	3.9	39.0		
	1037	4.0	39.2		
Station 16	1038	3.9	39.0	6.3	Clear light green
	1039	3.5	38.3		
	1040	3.4	38.1		
	1041	3.4	38.1		
	1042	3.6	38.5		
	1043	3.5	38.3		
	1044	3.6	38.5		

RETURNED TO BENTON HARBOR

9 June 1971
Wind NW-W 5-10 mph

Location	Time	Temperature		Secchi Transparency	Water color
Pierheads	1449	18.0	64.4		milky brown
	1450	17.5	63.5		
	1451	17.0	62.6		
	1452	16.7	62.1		
	1453	13.0	55.4		
	1454	13.0	55.4		
	1455	13.0	55.4		
	1456	14.0	57.2		
	1457	13.0	55.4		
	1458	13.5	56.3		
Station 1	1459	12.5	54.5	3.3	milky light brownish green
	1500	12.7	54.9		
	1501	12.8	55.0		
	1502	12.8	55.0		
	1503	12.8	55.0		
	1504	12.8	55.0		
	1505	12.9	55.2		
	1506	12.9	55.2		
	1507	12.9	55.2		
	1508	12.9	55.2		
	1509	12.9	55.2		
	1510	12.6	54.7		
	1511	12.5	54.5		
	1512	12.5	54.5		
	1513	12.5	54.5		

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TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 2	1514	12.5°C	54.5°F	4.5 m	clear green
	1515	12.5	54.5		
	1516	12.5	54.5		
	1517	12.5	54.5		
	1518	12.5	54.5		
	1519	12.5	54.5		
	1520	12.5	54.5		
Station 3	1521	12.5	54.5	4.5	clear green
	1522	12.0	53.6		
	1523	12.1	53.8		
	1524	12.2	54.0		
	1525	12.2	54.0		
	1526	12.2	54.0		
	1527	12.3	54.1		
	1528	12.3	54.1		
	1529	12.0	53.6		
	1530	12.0	53.6		
Station 4	1531	12.0	53.6	4.5	clear green
	1532	12.0	53.6		
	1533	12.0	53.6		
	1534	12.0	53.6		
	1535	12.0	53.6		
	1536	12.0	53.6		
	1537	12.0	53.6		
	1538	12.0	53.6		
Station 5	1539	12.0	53.6	4.5	clear green
	1540	12.0	53.6		
	1541	11.7	53.1		
	1542	11.5	52.7		
	1543	11.8	53.2		
	1544	11.9	53.4		
	1545	11.9	53.4		
	1546	11.7	53.1		
	1547	11.9	53.4		
Station 6	1548	11.9	53.4	5.0	clear dark green
	1549	11.8	53.2		
	1550	11.5	52.7		
	1551	11.5	52.7		
	1552	11.5	52.7		
	1553	11.5	52.7		
	1554	11.5	52.7		
	1555	11.5	52.7		
	1556	11.7	53.1		

—continued

TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 7	1557	11.7°C	53.1°F	5.5 m	clear dark green
	1558	11.5	52.7		
	1559	11.5	52.7		
	1600	11.2	52.2		
	1601	11.0	51.8		
	1602	11.0	51.8		
	1603	11.0	51.8		
	1604	10.9	51.6		
	1605	10.9	51.6		
Station 8	1606	11.0	51.8	5.5	clear dark green
	1607	10.9	51.6		
	1608	10.9	51.6		
	1609	10.9	51.6		
	1610	11.0	51.8		
	1611	11.0	51.8		
	1612	11.0	51.8		
	1613	10.9	51.6		
Station 9	1614	10.8	51.4	5.5	clear dark green
	1615	10.7	51.3		
	1616	10.5	50.9		
	1617	10.2	50.4		
	1618	9.9	49.8		
	1619	9.9	49.8		
	1620	9.9	49.8		
Station 10	1621	9.7	49.5	5.0	clear dark green
	1622	9.6	49.3		
	1623	9.8	49.6		
	1624	9.8	49.6		
	1625	9.8	49.6		
	1626	9.8	49.6		
	1627	9.9	49.8		
	1628	9.9	49.8		
Station 11	1629	9.9	49.8	5.5	clear dark green
	1630	9.9	49.8		
	1631	9.8	49.6		
	1632	9.8	49.6		
	1633	9.6	49.3		
	1634	9.5	49.1		
	1635	9.5	49.1		
	1636	9.6	49.3		
	1637	9.5	49.1		

--continued

TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 12	1638	9.2°C	48.6°F	6.0 m	clear dark green
	1639	9.0	48.2		
	1640	9.0	48.2		
	1641	9.0	48.2		
	1642	8.9	48.0		
	1643	8.5	47.3		
	1644	9.0	48.2		
	1645	9.0	48.2		
	1646	9.0	48.2		
Station 13	1647	8.9	48.0	6.0	clear dark green
	1648	8.9	48.0		
	1649	8.8	47.8		
	1650	9.0	48.2		
	1651	8.9	48.0		
	1652	8.9	48.0		
	1653	8.9	48.0		
	1654	8.5	47.3		
	1655	8.5	47.3		
Station 14	1656	8.5	47.3	6.0	
	1657	8.9	48.0		
	1658	8.9	48.0		
	1659	9.0	48.2		
	1700	9.0	48.2		
	1701	9.0	48.2		
	1702	8.9	48.0		
	1703	9.0	48.2		
	1704	9.0	48.2		
	1705	9.0	48.2		
	1706	9.0	48.2		
Station 15	1707	8.5	47.3	6.0	
	1708	8.6	47.5		
	1709	8.2	46.8		
	1710	8.5	47.3		
	1711	8.2	46.8		
	1712	8.1	46.6		
	1713	8.0	46.4		
	1714	8.0	46.4		
	1715	8.0	46.4		
	1716	8.0	46.4		
	1717	7.9	46.2		

--continued

TABLE 6 continued

Location	Time	Temperature		Secchi Transparency	Water color
Station 16	1718	7.9°C	46.2°F	5.0 m	clear dark green
	1719	7.7	45.9		
	1720	7.5	45.5		
	1721	7.5	45.5		
	1722	7.7	45.9		
	1723	7.7	45.9		
	1724	7.7	45.9		
	1725	7.5	45.5		
	1726	7.9	45.9		
	1727	8.0	46.4		
	1728	7.9	46.2		
	1729	7.7	45.9		
Station 17	1730	7.5	45.5	6.0	clear dark green
	1731	7.3	45.1		
	1732	7.5	45.5		
	1733	7.5	45.5		
	1734	7.3	45.1		
	1735	7.3	45.1		
	1736	7.5	45.5		
	1737	7.3	45.1		
	1738	7.3	45.1		
	1739	7.3	45.1		
	1740	7.2	45.0		
Station 18	1741	7.2	45.0	5.8	clear dark green
	1742	7.3	45.1		

RETURNED TO BENTON HARBOR

TABLE 7. Phytoplankton, Campbell Plant, W-1, Willow Run flyover. April 22, 1971. Water temperature: 6°C. 50 yds northwest of discharge, outside of plume.

Organism	Cells/ml.
Cyclotella and Stephanodiscus	7,652
Chlamydomonas	458
Synedra acus	293
Gomphonema olivacloides	57
Cryptomonas sp.	135
Navicula sp.	128
Diatoma tenue v. elongatum	202
Nitzschia sp.	137
Tabellaria fenestrata	85
Epithemia sp.	2
Meridion circularae	7
Rhoicosphaeria curvata	4
Kirchneriella sp.	6
Ankistrodesmus falcatus	20
Achnanthes sp.	6
Cocconeis sp.	4
Mallomonas sp.	9
Synedra ulna	98
Synedra ulna v. chaesana	19
Synedra ulna v. danica	4
Fragilaria crotonensis	617
Asterionella formosa	427
Melosira italica	41
Melosira islandica	371
Melosira binderana	386
Melosira granulata v. angustissima	282
Melosira granulata	456
Stephanodiscus hantzschii	306
Amphora ovalis v. pediculus	7
Amphora ovalis v. libyca	9
Fragilaria intermedia	126
Rhizosolenia eriensis	4
Peridinium sp.	24
Melosira varians	13
Cymatopleura solea	4
Fragilaria pinnata	4
Fragilaria construens	4
Scenedesmus sp.	6
Scenedesmus incrassatulus	4
Euglena sp.	6
Dinobryon divergens	13

TABLE 7 continued

Organism	Cells/ml.
Oocystis sp.	4
Gloeocystis sp.	2
Stauroneis sp.	2
Oscillatoria sp.	2
Surirella sp.	6
Diploneis sp.	2
Stephanodiscus transilvanicus	19
Fragilaria capucina	6
Diatoma vulgare	2

TABLE 8. Phytoplankton, Campbell Plant, W-2, Willow Run flyover. April 22, 1971. Water temperature: 21°C. Directly in discharge channel.

Organism	Cells/ml.
Cyclotella and Stephanodiscus	2,273
Chlamydomonas sp.	112
Synedra acus	153
Ankistrodesmus falcatus	13
Cryptomonas sp.	64
Dictyosphaerium pulchellum	1
Diatoma vulgare	2
Peridinium sp.	3
Cymbella sp.	3
Rhoicosphaeria curvata	2
Scenedesmus quadricauda	3
Phormidium sp.	4
Asterionella formosa	425
Stephanodiscus hantzschii	550
Melosira granulata	470
Melosira islandica	472
Melosira granulata v. angustissima	213
Melosira italica	23
Stephanodiscus transilvanicus	17
Fragilaria construens	13
Fragilaria crotonensis	301
Fragilaria capucina	36
Fragilaria intermedia	54
Nitzschia dissipata	4
Nitzschia sp.	48
Gomphonema olivaceoides	6
Cocconeis sp.	3
Cosmarium sp.	1
Mallomonas sp.	12
Tabellaria fenestrata	70
Euglena sp.	2
Diatoma elongatum	6
Diatoma tenue v. elongatum	78
Melosira varians	17
Surirella sp.	10
Achnanthes sp.	9
Caloneis ventricosa	1
Synedra ulna	18
Synedra ulna v. chaesana	8
Cymatopleura solea	2
Nitzschia recta	3
Dinobryon divergens	21

TABLE 8 continued

Organism	Cells/ml.
Scenedesmus incrassatulus	1
Amphora ovalis v. libyca	6
Amphora ovalis	1
Navicula sp.	40
Meridion circulare	4
Melosira binderana	240
Oocystis sp.	1

TABLE 9. Phytoplankton, Campbell Plant, Discharge, Willow Run flyover. April 28, 1971. In discharge channel.

Organism	Cells/ml.
Fragilaria capucina	11
Fragilaria intermedia	2
Melosira islandica	24
Cryptomonas	202
Nitzschia sp.	61
Tabellaria fenestrata	210
Chlamydomonas sp.	928
Synedra acus	37
Cyclotella and Stephanodiscus	729
Peridinium sp.	7
Asterionella formosa	165
Synedra filiformis	143
Oscillatoria sp.	24
Phormidium sp.	6
Fragilaria construens	69
Navicula sp.	37
Mallomonas sp.	43
Surirella sp.	4
Gomphonema sp.	6
Rhoicosphaeria curvata	2
Cocconeis sp.	9
Diatoma tenue v. elongatum	65
Diatoma tenue	11
Rhizosolenia longiseta	13
Dictyosphaerium pulchellum	22
Rhizosolenia eriensis	2
Amphora ovalis v. pediculus	9
Synedra ulna	28
Ankistrodesmus falcatus	37
Achnanthes sp.	11
Scenedesmus abundans	11
Scenedesmus sp.	39
Gloeocystis sp.	6
Tetraëdron sp.	2
Tetraëdron minimum	2
Synedra ulna v. danica	7
Fragilaria crotonensis	78
Melosira granulata	83
Melosira granulata v. angustissima	154
Melosira binderana	167

TABLE 9 continued

Organism	Cells/ml.
Mougeotia sp.	2
Oocystis sp.	2
Actinastrum hantzschii	2
Stephanodiscus hantzschii	187
Scenedesmus opoliensis	4
Synedra ulna v. chaesana	2
Kirchneriella sp.	4
Coelastrum sp.	7
Gomphosphaeria lacustris	2
Pediastrum sp.	2
Dinobryon divergens	2

TABLE 10. Phytoplankton, Campbell Plant, W-1, Willow Run flyover, April 30, 1971. In discharge channel, 1/2 mile offshore.

Organism	Cells/ml.
Fragilaria crotonensis	351
Fragilaria intermedia	15
Fragilaria capucina	104
Nitzschia sp.	50
Navicula sp.	44
Synedra acus	15
Cyclotella and Stephanodiscus	3,704
Tabellaria sp.	48
Diatoma tenue v. elongatum	85
Melosira granulata	267
Melosira binderana	39
Melosira italica	11
Melosira varians	4
Melosira granulata v. angustissima	239
Synedra ulna	11
Synedra ulna v. chaesana	2
Gomphonema sp.	7
Asterionella formosa	69
Achnanthes sp.	2
Scenedesmus sp.	2
Phormidium sp.	13
Scenedesmus abundans	4
Cocconeis sp.	4
Amphora ovalis v. libyca	17
Unknown flagellates	28
Stephanodiscus transilvanicus	4
Synedra filiformis	52
Synedra ulna v. danica	7
Achnanthes clevei	2
Diatoma tenue v. parchycephalum	2
Amphora ovalis v. pediculus	2
Fragilaria construens	13
Synedra ostenfeldii	43
Synedra sp.	2

TABLE 11. Phytoplankton, Campbell Plant, W-2, Willow Run flyover. April 30, 1971.

Organism	Cells/ml.
Amphora ovalis v. pediculus	1
Dinobryon divergens	4
Fragilaria intermedia	4
Navicula sp.	2
Cyclotella sp.	144
Chlamydomonas sp.	155
Synedra acus	31
Fragilaria crotonensis	44
Cryptomonas sp.	50
Mallomonas sp.	16
Tabellaria fenestrata	19
Fragilaria capucina	1
Melosira granulata	87
Melosira granulata v. angustissima	169
Asterionella formosa	17
Peridinium sp.	5
Nitzschia sp.	8
Phormidium sp.	5
Melosira islandica	29
Scenedesmus sp.	9
Stephanodiscus transilvanicus	3
Synedra ulna v. danica	4
Synedra ulna v. chaesana	7
Synedra filiformis	7
Chroococcus limneticus	1
Closterium sp.	2
Ankistrodesmus falcatus	11
Tetraëdron minimum	1
Achnanthes clevei v. rostrata	1
Stephanodiscus niagarae	1
Gomphonema sp.	1
Scenedesmus abundans	1
Oscillatoria sp.	1
Amphora ovalis	1
Oocystis sp.	1

TABLE 12. Phytoplankton, Campbell Plant, W-3, Willow Run flyover. April 30, 1971. Water temperature: 5°C. 300-400 yards east of W-2.

Organism	Cells/ml.
Chlamydomonas sp.	330
Cyclotella sp.	581
Cryptomonas sp.	48
Dinobryon divergens	6
Tabellaria fenestrata	24
Synedra ulna v. chaesana	9
Synedra ulna v. danica	9
Synedra acus	50
Synedra ulna	6
Asterionella formosa	41
Diatoma tenue	11
Achnanthes sp.	4
Closterium sp.	9
Peridinium sp.	17
Ankistrodesmus falcatus	15
Oscillatoria sp.	2
Fragilaria capucina	6
Scenedesmus sp.	7
Oocystis sp.	4
Mallomonas sp.	6
Cocconeis sp.	2
Nitzschia sp.	24
Fragilaria crotonensis	180
Melosira granulata	122
Melosira islandica	117
Melosira granulata v. angustissima	271
Stephanodiscus transilvanicus	4
Cymatopleura solea	2
Navicula sp.	4
Gomphosphaeria lacustris	4
Fragilaria intermedia	15

TABLE 13. Phytoplankton, Campbell Plant, Intake, Willow Run flyover. May 25, 1971.

Organism	Cells/ml.
Cocconeis sp.	7
Surirella sp.	4
Cymbella sp.	7
Diatoma tenue v. parchycephalum	6
Diatoma tenue v. elongatum	78
Pediastrum sp.	2
Melosira islandica	31
Stephanodiscus Hantzschii	85
Fragilaria intermedia	48
Navicula reinhardtii	2
Rhoicosphaeria curvata	2
Tabellaria fenestrata	284
Cyclotella sp.	1,154
Chlamydomonas	80
Synedra acus	85
Synedra filiformus	172
Nitzschia sp.	93
Nitzschia dissipata	4
Navicula sp.	33
Dinobryon divergens	30
Ankistrodesmus falcatus	13
Cryptomonas sp.	61
Oscillatoria sp.	6
Fragilaria crotonensis	364
Synedra ulna	26
Rhizosolenia eriensis	13
Rhizosolenia longiseta	41
Scenedesmus sp.	43
Scenedesmus abundans	31
Tetraëdron sp.	2
Achnanthes sp.	17
Phormidium sp.	7
Oocystis sp.	15
Dictyosphaerium pulchellum	6
Mallomonas sp.	2
Asterionella formosa	219
Melosira granulata	198
Melosira binderana	293
Synedra ostenfeldii	108
Quadrigula lacustris	4

TABLE 13 continued

Organism	Cells/ml.
Achnanthes affinis	2
Scenedesmus dimorphus	2
Amphora ovalis	2
Synedra ulna v. chaesana	2
Mougeotia sp.	2

B. SURVEYS OF EXISTING WARM WATER PLUMES

During 1971 surveys of existing warm water plumes were carried out on the following dates at the generating stations indicated.

June 6--Bailly Generating Station NIPSCO

June 9--Michigan City Generating Station NIPSCO

June 14--Point Beach Nuclear Plant Wis. Elect.-Wis.-Mich.

June 15-- " "

Oct. 2-- " "

Each of the surveys had several objectives:

1) to determine as well as possible the effects on plankton and coliform bacteria of passage through the plant
2) to determine the effect on the level of dissolved oxygen of passage through the plant
3) to map the three dimensional extent of the thermal plume from discharged cooling water.

Table 14 is a summary of the plant data on the dates the surveys were conducted. The drift duration is the release to retrieval time the bagged discharge water drifted in the plume.

The floating-bag technique was described in Part VII of our report series. It will not be repeated here in detail. Our 1970 NIPSCO Bailly Plant experiment indicated improvements desired on our technique and these changes were included in our 1971 field work. The improvements were:

TABLE 14. Plant data and drift duration, bag experiments, 1971.

Place and Date	Bag filling time*	Chlorination time	Load and flow	Wind conditions	Drift duration
Bailly 6 VI 71	1010	11:00	162,800 KW 141,022 GPM $\Delta T = 11.1^{\circ}C$	W-10 MPH later changed to ESE 22-30 MPH	$2^h\ 39^m$
Michigan City 9 VI 71	0953	10:00 14:00	184,000 KW 241,000 GPM $\Delta T = 6.1^{\circ}C$	SE 4-7 MPH	$2^h\ 11^m$
Point Beach 14 VI 71	1236	no chlorination	496,500 KW 347,000 GPM $\Delta T = 10^{\circ}C$	E 0-2 MPH	$1^h\ 58^m$
Point Beach 15 VI 71	1115	no chlorination	498,000 KW 347,000 GPM $\Delta T = 10.3^{\circ}C$	NE 0-3 MPH	$2^h\ 33^m$
Point Beach 2 X 71	0942	no chlorination	480,500 KW 347,000 GPM $\Delta T = 7.8^{\circ}C$	SSE 10 MPH	$0^h\ 53^m$

* This column gives the latest time outfall water was filled in bags.

1) 90 quarts of water was used for each bag.

2) All bags were duplicated.

3) #10 net was used for zooplankton sampling.

4) The Winkler method was used for determining dissolved oxygen levels.

5) Each bag contained a YSI Model 401 Thermistor with an external connector for temperature monitoring without disturbing the bag content. All thermistors were cross-calibrated and matched for each set of bags.

6) C_{14} uptake experiment[1] was added as a further check on phytoplankton mortality indication.

The bags were marked by letters as follows:

I = intake water

O = outfall water

P = drifted along in the plume

A = anchored at intake ambient temperature

Intake water was transported in 30 gallon plastic containers to the outfall where 90 quarts were transferred to each of two clear plastic bags. The bags were then tied together with a thermistor in each and floated down the plume (IP). Outfall water was transported in the plastic cans to the intake and 90 quarts were transferred into each of two bags; these were tied with thermistors inside and anchored at the intake (OA). Ninety quarts of intake water were placed in each of two bags tied with thermistors inside and anchored at the intake (IA). Similarly paired bags were filled at the outfall and floated down the plume (OP).

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[1] The method follows that used by Schelske and Callender. 1970. Survey of phytoplankton productivity and nutrients in Lake Michigan and Lake Superior. Proc. 13th Conf. Great Lakes Res., p.93-105.

The ZODIAC, our small boat, then ran between the ambient bags and plume bags to check the bag temperatures against the surrounding water about every 15 minutes. When the temperature inside the plume bags and the surrounding water and water at intake were within $1^{o}F$ from each other, the bagged water was sampled.

Sampling consisted of raising and opening each bag mouth and immersing sampling bottles for bacteria, phytoplankton, and C_{14} uptake samples. The remaining water in the bag was transferred by bucket through a #10 zooplankton net and collected in a wide mouth mason jar. The samples were then transported to the R/V MYSIS for processing.

The phytoplankton samples were preserved with Utermohl's iodine solution. Later in the laboratory they were concentrated and identified. The results of all species and counts in each bag are summarized in Tables 15 - 17. All the counts and the mean of the duplicate bags are rounded off to the nearest thousand. The numbers are highly variable even between some duplicate bags which were filled within minutes of each other. This is consistant with our 1970 observation, and further indicates the patchiness of the phytoplankton population. Also the highest population is at Michigan City and the lowest at Point Beach, which is consistant with the general condition of the lake.

The Carbon-14 samples were obtained by dipping a 260 milliliter glass bottle in the bag. After the samples from all bags were gathered on the R/V MYSIS, 2 ml of lake water was removed from each sample bottle and 2 ml of 1 microcurie/ml C-14 solution was injected into each

TABLE 15. Phytoplankton. Summary table to bag experiments at Bailly, 6 June 1971. Thousands of cells per liter.

Genera and species	IP-1	IP-2	IP-mean	IA-1	OA-1	OP-1	OP-2	OP-mean
DIATOMS								
Synedra filiformis	6	6	6	8	10	14	6	10
Synedra delicatissima	10	14	12	14	14	10	11	10
Synedra ostenfeldi	31	20	26	32	28	27	21	24
Synedra ulna	2	1	2	3	3	7	5	6
Synedra spp.	-	-		-	1	-	1	1
Rhizosolenia gracilis	31	22	27	52	55	39	46	43
Rhizosolenia spp.	-	-		-	-	-	1	1
Rhizosolenia eriensis	-	-		1	-	-	-	-
Cyclotella spp.	30	18	24	23	25	19	5	12
Asterionella formosa	19	10	15	11	14	16	13	15
Diatoma tenue	1	-	1	6	4	2	1	2
Diatoma tenue v. elongatum	51	5	28	19	14	17	3	10
Fragilaria capucina	11	15	13	11	29	25	13	19
Fragilaria crotonensis	22	50	36	40	25	91	39	65
Fragilaria pantocsekii v. binodis	-	-	-	-	1	-	-	
Navicula spp.	1	1	1	2	1	2	1	2
Navicula radiosa?	-	-	-	-	-	-	1	1
Nitzschia spp. (our #2)	1	-	1	-	1	1	-	1
Nitzschia spp.	6	1	4	1	1	3	-	2
Nitzschia acicularis	1	1	1	1	3	5	-	3
Denticula tenuis v. crassula	-	1	1	-	-	-	-	-
Achnanthes spp.	-	-	-	-	-	1	-	1
Stephanodiscus binderanus	4	3	4	9	8	4	5	5
Stephanodiscus spp.	49	45	47	39	36	33	24	29
Surirella angustata	-	-	-	-	-	-	1	1
Melosira islandica	1	-	1	-	1	6	1	4

continued--

TABLE 15 continued

Genera & species	IP-1	IP-2	IP-mean	IA-1	OA-1	OP-1	OP-2	OP-mean
Melosira spp.	1	-	1	-	1	6	1	4
Tabellaria fenestrata	32	31	32	139	40	42	58	50
Cocconeis placentula v. euglypta	-	-	-	1	-	-	-	-
Cocconeis spp.	-	-	-	1	-	-	-	-
Diploneis oculata	-	-	-	1	-	-	-	-
Diploneis spp.	-	-	-	1	-	-	-	-
Unknown diatoms	13	15	14	4	6	1	-	1
BLUE-GREENS								
Microcystis spp.	1	-	1	-	-	-	-	-
Oscillatoria spp.	1	1	1	4	2	1	1	1
Gomphosphaeria spp.	1	1	1	-	-	1	-	1
Chamaesiphon spp.	-	-	-	-	-	-	2	1
Anacystis spp.	-	3	2	2	2	-	-	-
Unknown blue-green filament	51	44	48	52	52	38	13	26
Unknown blue-green colonial	-	1	1	-	-	1	-	1
GREENS								
Cosmarium spp.	2	1	2	1	3	1	1	1
Oocystis spp.	1	2	2	3	3	1	2	2
Scenedesmus spp.	4	6	5	4	2	9	4	7
Scenedesmus bijuga	1	-	1	-	1	1	1	1
Scenedesmus dimorphus	1	1	1	1	1	1	-	1
Scenedesmus bijuga v. alternans	-	1	1	-	-	-	-	-
Scenedesmus quadricauda	-	-	-	1	1	1	-	1
Scenedesmus ?	-	-	-	1	1	-	-	-
Scenedesmus quadricauda ?	-	-	-	-	-	-	1	1

continued--

TABLE 15 continued

Genera & species	IP-1	IP-2	IP-mean	IA-1	OA-1	OP-1	OP-2	OP-mean
Ankistrodesmus falcatus v. mirabilis	24	116	70	26	24	18	25	22
Ankistrodesmus gelifactum	-	1	1	1	1	-	-	-
Ankistrodesmus spiralis	2	4	3	-	-	-	-	-
Ankistrodesmus spp.	1	-	1	-	-	-	-	-
Penium spp.	6	12	9	9	5	4	-	2
Mougeotia spp.	1	-	1	1	-	1	-	1
Actinastrum hantzschii	3	3	3	1	5	3	1	2
Coelastrum spp.	1	-	1	-	-	-	-	-
Gloeocystis spp.	1	-	1	17	12	1	1	1
Westella botryoides	88	72	80	83	66	6	2	4
Crucigenia quadrata	-	1	1	-	-	-	1	1
Crucigenia spp.	-	-	-	1	1	1	-	1
Closteridium spp.	-	1	1	2	1	-	-	-
Golenkinia paucipina	-	1	1	-	-	-	-	-
Pediastrum spp.	1	-	1	-	-	-	-	-
Micractinium spp.	-	-	-	-	-	1	-	1
Coleochaete	-	-	-	-	-	-	1	1
Franceia spp.	-	-	-	1	-	-	-	-
Sphaerocystis	-	-	-	-	3	-	-	-
Unknown green solitary	11	65	38	14	5	18	12	15
Unknown green filament	5	2	4	1	3	1	1	1
Unknown green colonial	-	3	2	1	2	1	-	1
Unknown desmid	1	2	2	4	1	1	-	1
Closteriopsis longissima	2	3	3	1	-	5	3	4
FLAGELLATES								
Chlamydomonas spp.	2	1	2	-	1	2	4	3
Phacus	1	2	2	1	2	1	1	1
Unknown flagellates	5	3	4	3	3	4	3	4

continued--

TABLE 15 continued

Genera & species	IP-1	IP-2	IP-mean	IA-1	OA-1	OP-1	OP-2	OP-mean
CHRYSOPHYTES								
Dinobryon divergens	32	16	24	17	25	17	32	25
DINOFLAGELLATES								
Peridinium spp.	1	1	1	1	-	-	-	-

TABLE 16. Phytoplankton. Summary table to bag experiments at Michigan City, 9 June, 1971. Thousands of cells per liter.

Genera & species	IP-1	IP-2	IP-mean	OP-1	OP-2	OP-mean	IA-1	IA-2	IA-mean	OA-1	OA-2	OA-mean
DIATOMS												
Stephanodiscus spp.	452	422	437	99	424	262	259	227	243	591	473	532
Sephanodiscus binderanus	269	438	354	35	271	153	309	297	303	383	291	337
Stephanodiscus minutus	-	-	-	-	-		23	-	12	-	2	1
Stephanodiscus tenuis	-	-	-	-	-		8	5	7	-	-	-
Cyclotella spp.	318	260	289	48	197	123	248	215	232	288	376	332
Cyclotella michiganiana	-	-	-	-	-		54	7	31	-	-	-
Fragilaria spp.	9	9	9	3	16	10	-	-	-	28	16	22
Fragilaria crotonensis	67	123	95	23	23	23	6	58	32	93	60	77
Fragilaria capucina	-	-	-	14	-	7	-	-		-	-	-
Asterionella formosa	7	14	11	1	9	5	8	23	16	19	30	25
Nitzschia spp.	23	42	33	5	19	12	63	39	51	16	46	31
Nitzschia acicularis	2	-	1	1	2	2	10	5	8	2	-	1
Nitzschia spp. (our #2)	-	-	-	-	-	-	4	2	3	-	-	-
Nitzschia confinis	-	-	-	-	-	-	2	-	1	-	-	-
Nitzschia bacata	-	-	-	-	-	-	2	-	1	-	-	-
Diatoma vulgare	-	-	-	-	-	-	4	2	3	-	2	1
Diatoma tenue	2	-	1	1	-	1	10	-	5	-	-	-
Diatoma tenue v.elongatum	7	12	10	-	9	5	2	9	6	7	5	6
Synedra filiformis	5	5	5	2	7	5	2	5	4	9	5	7
Synedra delicatissima	2	35	19	7	2	5	21	14	18	28	51	40
Synedra ostenfeldi	14	39	27	6	2	4	25	9	17	37	49	43
Synedra ulna	2	7	5	11	6	9	6	16	11	19	21	20
Synedra delicatissima v. angustissima	-	-	-	-	-	-	6	-	3	-	-	-
Synedra spp.	-	-	-	1	-	1	-	-	-	-	-	-

continued--

TABLE 16 continued

Genera & species	IP-1	IP-2	IP-mean	OP-1	OP-2	OP-mean	IA-1	IA-2	IA-mean	OA-1	OA-2	OA-mean
Melosira spp.	14	9	12	7	37	22	10	26	18	46	26	36
Melosira varians	-	-	-	-	-	-	-	-	-	-	16	8
Gomphonema	9	2	6	1	2	2	0	9	5	5	2	4
Tabellaria fenestrata	77	97	87	40	125	85	63	39	51	139	111	125
Navicula spp.	35	35	35	3	2	3	63	44	54	26	23	25
Navicula integra	-	-	-	1	-	1	-	-	-	-	-	-
Navicula capitata	-	-	-	-	-	-	4	2	3	2	-	1
Navicula capitat v. lune-burgensis	-	-	-	1	-	1	-	-	-	-	-	-
Navicula radiosa	-	-	-	-	-	-	-	-	-	-	2	1
Rhizosolenia gracilis	5	12	9	1	9	5	46	30	38	9	7	8
Amphora ovalis	-	2	1	-	-	-	-	-	-	2	-	1
Amphora spp.	-	-	-	-	-	-	-	2	1	-	-	-
Diploneis spp.	-	2	1	-	-	-	-	-	-	-	-	-
Cymbella spp.	-	-	-	-	-	-	2	-	1	-	-	-
Cymbella ?	-	-	-	-	2	1	-	-	-	-	-	-
Achnanthes affinis	-	-	-	-	-	-	2	-	1	-	-	-
Neidium spp.	-	-	-	-	-	-	-	-	-	-	5	3
Cymatopleura solea	-	-	-	-	-	-	-	-	-	-	2	1
Unknown diatoms	21	23	22	4	23	14	27	30	29	72	56	64
BLUE-GREENS												
Unknown blue-green colonial	-	-	-	-	-	-	4	-	2	-	-	-
Anacystis spp.	-	2	1	-	-	-	-	-	-	-	-	-
Oscillatoria spp.	-	2	1	2	5	4	-	-	-	-	-	-
Gomphosphaeria spp.	-	-	-	-	-	-	-	2	1	-	-	-
Microcystis spp.	-	-	-	-	-	-	-	2	1	-	-	-
Unknown blue-green filaments	90	37	64	13	72	43	138	49	94	56	79	68

continued--

TABLE 16 continued

Genera & species	IP-1	IP-2	IP-mean	OP-1	OP-2	OP-mean	IA-1	IA-2	IA-mean	OA-1	OA-2	OA-mean
GREENS												
Scenedesmus spp.	28	56	42	5	19	12	58	53	56	26	44	35
Scenedesmus dimorphus	-	-	-	1	-	1	4	2	3	-	2	1
Scenedesmus opoliensis v. contacta?	-	-	-	-	-	-	2	-	1	-	-	-
Scenedesmus quadricauda	-	-	-	-	-	-	10	-	5	-	-	-
Oedogonium spp.	51	-	26	24	63	44	-	-	-	-	-	-
Ankistrodesmus falcatus v. mirabilis	14	9	12	3	19	6	21	12	17	23	14	19
Ankistrodesmus spp.	-	-	-	-	-	-	-	-	-	-	2	1
Cladophora spp.	14	-	7	-	23	12	-	-	-	-	-	-
Closteridium spp.	2	-	1	-	-	-	-	-	-	-	-	-
Closteriopsis longissima	-	7	4	1	2	2	13	7	10	23	4	14
Westella botryoides	-	5	3	1	-	1	6	7	7	9	46	28
Gloeocystis spp.	-	-	-	2	5	4	14	9	12	2	16	14
Oocystis spp.	-	-	-	1	-	1	2	-	1	5	5	5
Sphaerocystis spp.	-	-	-	-	-	-	2	-	1	2	-	1
Crucigenia spp.	-	-	-	-	-	-	2	-	1	-	-	-
Cosmarium spp.	-	-	-	-	-	-	-	-	-	2	2	2
Unknown Desmid	-	-	-	-	-	-	-	-	-	2	-	1
Unknown green solitary	21	12	17	3	11	7	29	30	30	51	32	42
Unknown green filament	-	-	-	-	-	-	-	2	1	-	-	-
FLAGELLATES												
Unknown flagellates	-	2	1	1	5	3	-	7	4	16	5	11
CHRYSOPHYTES												
Dinobryon divergens	9	12	11	5	14	10	16	9	13	9	26	18
DINOFLAGELLATES												
Peridinium spp.	-	-	-	-	2	1	-	-	-	-	-	-

TABLE 17. Phytoplankton. Summary table of bag experiments at Point Beach, 14 June, 15 June, 1971. Thousands of cells per liter.

Genera & species	IP-1	IP-2	IP-mean	OP-1	OP-2	OP-mean	IA-1	IA-2	IA-mean	OA-1	OA-2	OA-mean
					14 June, 1971							
DIATOMS												
Melosira spp.	1	1	1	1	1	1	2	1	2	30	17	24
Tabellaria fenestrata	4	1	3	2	-	1	-	1	1	22	16	19
Stephanodiscus spp.	2	3	3	5	4	5	3	1	2	3	2	3
Diatoma tenue	-	1	1	-	-	-	-	-	-	-	-	-
Diatoma tenue v.elongatum	-	1	1	-	-	-	-	-	-	-	1	1
Diatoma vulagare	-	-	-	1	-	1	-	-	-	-	-	-
Cyclotella spp.	-	3	2	4	1	3	3	1	2	6	3	5
Fragilaria spp.	-	1	1	-	-	-	-	-	-	1	-	1
Fragilaria leptostauron	-	-	-	-	-	-	-	1	1	-	-	-
Rhizosolenia gracilis	-	-	-	1	-	1	1	-	1	1	1	1
Navicula spp.	-	-	-	-	1	1	-	-	-	-	1	1
Synedra ostenfeldi	-	-	-	-	1	1	-	-	-	1	-	1
Synedra ulna	-	-	-	-	-	-	1	-	1	-	1	1
Synedra delicatissima	-	-	-	-	-	-	-	-	-	1	1	1
Synedra filiformis	-	-	-	-	-	-	-	-	-	-	1	1
Nitzschia spp.	-	-	-	-	-	-	-	-	-	1	-	1
Nitzschia acicularis	-	-	-	-	-	-	-	-	-	-	1	1
Gomphonema spp.	-	-	-	-	-	-	-	-	-	-	1	1
Unknown diatoms	-	1	1	2	-	1	1	1	1	2	1	2
BLUE-GREENS												
Anacystis spp.	-	1	1	1	-	1	1	-	1	-	1	1
Microcystis spp.	-	2	1	1	-	1	1	3	2	1	1	1
Oscillatoria spp.	-	1	1	1	1	1	-	-	-	2	1	2
Gomphosphaeria spp.	-	-	-	-	1	1	-	-	-	-	-	-
Unknown blue-green filament	4	9	7	7	9	8	6	2	4	10	7	9
Unknown blue-green colonial	-	1	1	-	-	-	1	-	1	-	-	-

continued-

TABLE 17 continued

Genera & species	IP-1	IP-2	IP-mean	OP-1	OP-2	OP-mean	IA-1	IA-2	IA-mean	OA-1	OA-2	OA-mean
GREENS												
Scenedesmus spp.	1	3	2	1	1	1	3	6	5	3	6	5
Ankistrodesmus falcatus v. mirabilis	2	2	2	3	4	4	6	3	5	4	6	5
Ankistrodesmus spp.	1	1	1	1	1	1	2	1	2	1	2	2
Golenkinia spp.	1	-	1	-	-	-	-	-	-	-	-	-
Closteriopsis longissima	1	1	1	1	1	1	1	-	1	-	1	1
Oocystis spp.	-	1	1	1	1	1	1	1	1	1	1	1
Cosmarium spp.	-	-	-	1	-	1	-	1	1	3	3	3
Gloecystis spp.	-	-	-	-	1	1	-	-	-	1	-	1
Westella botryoides?	-	-	-	-	1	1	-	2	1	-	-	-
Pediastrum boryanum	-	-	-	-	-	-	-	1	1	-	-	-
Pediastrum spp.	-	-	-	-	-	-	-	-	-	1	-	1
Westella spp.	-	-	-	-	-	-	-	-	-	2	-	1
Oedogonium spp.	-	-	-	-	-	-	-	-	-	-	1	1
Crucigenia spp.	-	-	-	-	-	-	-	-	-	-	1	1
Cladophora	-	-	-	-	-	-	-	-	-	-	1	1
Unknown green solitary	1	4	3	6	3	5	2	6	4	3	5	4
Unknown green filament	-	1	1	1	1	1	2	-	1	3	1	2
Unknown green colonial	-	1	1	1	-	1	-	-	-	-	-	-
Unknown desmid	-	-	-	1	-	1	-	-	-	-	-	-
FLAGELLATES												
Phacus	1	-	-	-	-	-	-	1	1	-	-	-
Mallomonas	-	-	-	-	1	1	-	-	-	-	-	-
Unknown flagellates	-	-	-	6	-	3	-	-	-	-	1	1

continued--

TABLE 17 continued

Genera & species	IP-1	IP-2	IP-mean	OP-1	OP-2	OP-mean	IA-1	IA-2	IA-mean	OA-1	OA-2	OA-mean
CHRYSOPHYTES												
Dinobryon divergens	37	31	34	64	76	70	29	21	25	83	57	70
Dinobryon spp.	-	-	-	-	-	-	1	-	1	-	-	-
DINOFLAGELLATES												
Peridinium	1	-	1	-	-	-	-	-	-	-	-	-
15 June, 1971												
DIATOMS												
Synedra filiformis	6	-	3	-	-	-	-	-	-	-	-	-
Synedra delicatissima	2	-	1	-	-	-	-	-	-	1	-	1
Synedra ostenfeldi	6	-	3	-	-	-	-	-	-	-	-	-
Synedra ulna	-	1	1	1	-	1	1	1	1	1	1	1
Synedra spp.	1	-	1	-	-	-	-	-	-	-	-	-
Navicula spp.	1	-	1	-	-	-	-	-	-	-	-	-
Fragilaria crotonensis	7	-	4	-	-	-	-	-	-	-	-	-
Fragilaria spp.	-	-	-	-	-	-	-	1	1	1	-	1
Asterionella formosa	2	-	1	-	-	-	-	-	-	-	-	-
Rhizosolenia gracilis	6	-	3	-	-	-	1	-	1	-	-	-
Stephanodiscus spp.	1	1	1	4	2	3	2	2	2	1	3	2
Cyclotella spp.	3	-	2	2	-	1	1	1	1	6	1	4
Diatoma tenue	1	-	1	-	-	-	-	-	-	1	1	1
Diatoma tenue v.elongatum	2	-	1	-	-	-	-	-	-	1	-	1
Tabellaria fenestrata	1	1	1	1	-	1	-	-	-	23	1	12

continued--

TABLE 17 continued

Genera & species	IP-1	IP-2	IP-mean	OP-1	OP-2	OP-mean	IA-1	IA-2	IA-mean	OA-1	OA-2	OA-mean
Melosira spp.	-	-	-	2	1	2	2	1	2	13	3	8
Nitzschia spp.	-	-	-	-	-	-	-	-	-	2	-	1
Unknown diatoms	4	-	2	1	1	1	-	-	-	1	-	1
BLUE-GREENS												
Microcystis spp.	1	1	1	1	-	1	-	-	-	1	1	1
Comphosphaeria spp.	1	-	1	1	-	1	-	-	-	-	-	-
Oscillatoria spp.	-	-	-	2	1	2	1	-	1	1	-	1
Anabaena spp.	-	-	-	-	-	-	1	-	1	1	-	1
Blue-green filament	1	1	1	6	2	4	5	3	4	13	6	10
Blue-green colony	-	-	-	-	1	1	-	-	-	-	-	-
GREENS												
Scenedesmus spp.	4	1	3	1	1	1	3	2	3	5	6	6
Ankistrodesmus spp.	1	1	1	1	1	1	1	1	1	2	1	2
Ankistrodesmus falcatus v.mirabilis	4	1	3	3	2	3	5	3	4	7	2	5
Gloeocystis spp.	2	-	1	-	3	2	1	-	1	1	1	1
Closteriopsis longissima	1	-	1	-	1	1	-	1	1	2	1	2
Cosmarium spp.	1	-	1	1	1	1	-	-	-	2	1	2
Oocystis spp.	1	1	1	1	2	2	-	-	-	1	-	1
Golenkinia spp.	-	1	1	-	-	-	-	-	-	-	1	1
Westella botryoides	-	-	-	2	1	2	1	1	1	23	2	13
Franceia?	-	-	-	-	1	1	-	1	1	-	-	-
Crucigenia spp.	-	-	-	-	1	1	-	-	-	-	-	-
Pandorina morum	-	-	-	-	-	-	-	1	1	-	-	-
Truebaria setigerum	-	-	-	-	-	-	-	-	-	1	-	1

continued------

TABLE 17 continued

Genera & species	IP-1	IP-2	IP-mean	OP-1	OP-2	OP-mean	IA-1	IA-2	IA-mean	OA-1	OA-2	OA-mean
Sphaerocystis sp.	-	-	-	-	-	-	-	-	-	1	-	1
Unknown green solitary	2	1	2	3	2	3	1	1	1	6	2	4
Unknown green filament	-	-	-	-	-	-	1	-	1	-	-	-
Unknown green colony	-	-	-	-	-	-	1	-	1	-	-	-
FLAGELLATES												
Unknown flagellates	-	-	-	-	1	1	1	-	1	-	-	-
CHRYSOPHYTES												
Dinobryon divergens	45	40	43	101	84	93	44	32	38	79	99	84

bottle. The bottles were closed off with a glass stopper and wrapped in a double layer of diffusing screen of 1.6 millimeter mesh. The dark bottle was also wrapped in aluminum foil. These bottles were then placed in an incubator box of clear plastic with flowing lake water to keep them at lake temperature and incubated in the daylight for four hours. At the end of the incubation these samples were filtered through Millipore 0.45 Micron HA filters. The filters were then mounted on planchets and counted by a Bechman Low Beta II planchet counter.

The Carbon-14 uptake experimental results are summarized in Table 18. The values given are ten minutes counts of β activities minus the background counts of the machines (in our instrument it is 10). Our technique did not allow us to compute for productivity directly since we used only one control bottle. Nevertheless, the carbon-14 ampules are from the same lot and the same amount (2 ml) was introduced in each bottle containing the same volume of lake water (260 ml). Each set of light bottles from the corresponding bags and the dark bottle from IA1 was incubated at the same time for four hours. The activity given by each sample therefore represents the uptake in each bottle by the amount of live phytoplankton present. The value shown is highly variable, and confirms the patchiness of the phytoplankton population as indicated in our species identification list given in Tables 15 - 17. It does not show the effect the passage through the plant might have on phytoplankton. If indeed there is any, we shall need many more sets of samples for any reasonably dependable statistical analysis.

TABLE 18. C-14 β-counts; summary table for bag experiments, 1971.

Bag	Bailly 6 VI 71	Mich.City 9 VI 71	Point Beach 14 VI 71	Point Beach 15 VI 71	Point Beach 2 X 71
IA1	1260	8966	243	232	3207
IA2	-	7958	230	373	3037
IP1	646	15225	158	200	
IP2	910	13521	75	335	
OA1	1048	8733	1480	661	4019
OA2	-	19176	930	721	4052
OP1	505	11757	343	1405	
OP2	701	12360	613	404	
DARK	61	1703	175	247	309

TABLE 19. Dissolved oxygen; summary table of bag experiments, 1971.

Source	Bailly 6 VI 71	Mich.City 9 VI 71	Point Beach 14 VI 71	Point Beach 15 VI 71	Point Beach 16 VI 71	Point Beach 2 X 71
Intake						
mg/l	10.35	7.8	12.9	12.6	12.4	12.0
% sat.	113%	90%	127%	123%	120%	105%
Outfall						
mg/l	10.35	8.0	12.5	12.5	12.7	11.6
% sat.	122%	98%	141%	141%	144%	120%

Dissolved oxygen measurements: The results of dissolved oxygen measurements are given in Table 19. Each value is the average of a pair of duplicate samples. The Winkler method of oxygen determination

TABLE 20. Bacteria; summary table for bag experiments, 1971. (Coliform cells/100 ml.)

Bag	IP1	IP2	IA1	IA2	OP1	OP2	OA1	OA2
Bailly 6 VI 71	Monitors were too wet. Bacteria grew in suspension, not as colonies.							
Mich.City 9 VI 71	All samples overgrown, too dense to count.							
Point Beach 14 VI 71	0	27	8	3	3	5	0	5
15 VI 71	0	0	5	2	0	2	4	0

was very consistant and the duplicate samples values are always within 0.1 milligram of each other. If there is an effect on the level of dissolved oxygen, it is not evident in our results. The saturation is naturally higher since it is a function of temperature. The real difference shown in our data is the difference in dissolved oxygen levels of the different locations, which is again consistent with the present condition of the lake.

Bacteria measurements: The Millipore sampler is not suitable for any large volume of work to be handled. It required much care on the part of the operator. We were not very successful with this experiment. The two sets of data we obtained, listed in Table 20, showed great variation between the duplicate samples. We can draw no conclusion from the small amount of data available.

The Zooplankton Experiment

After each bag was sampled for phytoplankton, bacteria and carbon-14 analysis, the remainder of the bag content (93.5 liters) was poured through a #10 zooplankton net and collected in a wide mouth mason jar. The sample was then immediately inspected under a microscope for mortality determination. Afterwards, the whole sample was preserved with buffered formalin for species identification. Unfortunately, in our June experiments the laboratory technician misinterpreted the zooplankton samples for benthos and a large number of the samples could not be recovered. The species identification list in June therefore does not include the Point Beach samples.

For our October experiment at Point Beach, we used a new procedure for separating the live and dead planktons, which allowed us to observe the response of each species to the passage through the plant. The zooplankton were separated into live and dead fractions by repeated additions of lake water samples followed by decantation after settling. The process was repeated until no further swimmer was observed. The separated fractions were then preserved and counted.

The zooplankton results, especially the mortality determination, to date indicate that they are probably the most sensitive indicators of effects on the passage through the plant. Table 21 gives the complete list of live to dead ratios from all bags and experiments. Again, there was a large variation in these ratios, even between duplicate bags that were filled within minutes of each other. The increase in bag volume did not smooth out the patchiness of the zooplankton

TABLE 21. Zooplankton; summary of bag experiments, 1971.

Bag	Time filled	Time Elapsed	Volume (liters)	Zoop./100 liter Live	Zoop./100 liter Dead	Live/dead ratio	Mean
			Michigan City 9 VI 71				
IP1	1055	2:13	93.5	48	22	2.18	1.66
IP2	1055	2:16	93.5	16	14	1.14	
OP1	1102	2:39	93.5	48	72	0.67	1.15
OP2	1102	2:46	93.5	41	25	1.64	
IA1	1133	2:49	93.5	25	27	0.93	0.86
IA2	1135	2:54	93.5	4	5	0.83	
OA1	1115	2:49	93.5	19	19	1.00	1.50
OA2	1115	2:56	93.5	102	51	2.00	
			Point Beach 14 VI 71				
IP1	1140	3:03	93.5	1	0	0	
IP2	1140	2:58	72.7	0	0		
OP1	1200	2:05	93.5	6	44	1.36	0.94
OP2	1200	2:15	93.5	57	111	0.51	
IA1	1237	2:29	93.5	2	1	2	
IA2	1239	2:18	93.5	0	0		
OA1	1227	2:11	93.5	15	27	0.56	0.89
OA2	1236	2:03	93.5	39	32	1.22	
			Point Beach 15 VI 71				
IP1	1055	2:13	93.5	9	20	0.45	
IP2	1055	2:16	-------- bag split ------------------				
OP1	1102	2:34	93.5	---------process error-----			
OP2	1102	2:46	93.5	182	94	1.94	
IA1	1135	2:49	93.5	75	36	2.08	3.79
IA2	1135	2:54	93.5	11	2	5.50	
OA1	1115	2:49	93.5	3	0		
OA2	1115	2:46	93.5	42	28	1.50	
			Point Beach 2 X 71				
I1	0921	Direct	95	99	17	5.82	5.71
I2	0919	sample	95	123	22	5.59	
O1	0927	from	95	246	151	1.63	1.16
O2	0930	source	95	168	243	0.69	
OP1	0942	--------------bag split -------------------------					
OP2	0938	1:28	93.5	571	172	3.32	

population. Except for the June 9th results at Michigan City, the highest live to dead ratios for all Point Beach experiments were obtained in IA bags. The IA bag at Michigan City gave the lowest mean live to dead ratio for that day.

The same data are displayed differently in Table 22 This table lists the mortality rates of zooplankton for each bag of all five experiments. The mortality rate is merely the percentage of dead zooplankton out of the total population in each bag. We can thus lump all five experiments together for statistical analysis, and obtain a clearer picture. The bottom of each column in Table 22 gives the mean value, standard deviation and standard error estimate of the mean for the four sets of bags (IP, IA, IP, OA) and all values. We then use the null hypotheses that there is no difference between each column mean and the over-all mean and test the hypothesis using the student's t distribution on the difference of two means. We can reject the hypothesis for the following columns, IP, IA, OP, OA with the respective confidence levels: $\sim$70%, $\sim$95%, <60%, <30%. In other words, the only significant result of the test is that the IA column is indeed different and the lowest. It suggests therefore that the passage through the plant may cause an increase in the zooplankton mortality rate. We are however unable, with out data, to isolate the specific factor contributing to this effect. In view of the patchiness of the zooplankton distribution, we shall need more frequent sampling before any specific effect may show up in the analysis.

TABLE 22. Mortality of zooplankton (% dead); bag experiments, 1970 and 1971.

Bag	IP1	IP2	IA1	IA2	OP1	OP2	OA1	OA2
Bailly 20 VI 70	71	67	47	48	54	62	66	62
Mich.City 9 VI 71	31	47	52	56	60	38	50	33
Pt.Beach 14 VI 71	0/1	0/0	33	0/0	88	66	64	45
Pt.Beach 15 VI 71	69	N.D.	32	15	N.D.	34	0/3	40
Pt.Beach 2 X 71	N.D.	N.D.	15	15	N.D.	23	38	59
Mean	57.0		34.8		53.1		50.8	
Std. Deviation S	17.4		16.8		20.7		12.4	
Std.Error $S/\sqrt{n}$	7.8		5.6		7.3		4.1	
Number of samples	5[1]		9		8		9[1]	

Overall mean = 47.7
S = 18.2
$S_{\bar{x}}$ = 3.3
n = 31

[1] The zero values are not used since they were obtained from samples with ONE count and THREE counts respectively.

TABLE 23. Mortality of zooplankton by species. Point Beach Power Plant, October 2, 1971.

Species	I	I2	I1 + I2	O1	O2	OP2	Outfall total	O-I
Bosmina								
Live	20	67	87	171	81	180	432	
Dead	9	10	19	38	75	79	192	
Mortality	31%	13%	18%	18%	48%	31%	31%	13%
Cyclopoids								
Live	31	27	58	45	28	267	340	
Dead	4	5	9	92	125	70	287	
Mortality	11%	16%	13%	67%	82%	21%	46%	33%
Diatomids								
Live	25	7	32	6	19	68	93	
Dead	3	4	7	9	21	6	36	
Mortality	11%	36%	18%	60%	53%	8%	28%	19%
Asplanchna								
Live	6	1	7	-	1	5	6	
Dead	0	1	1	-	0	0	0	
Mortality	0%	50%	14%	-	0%	2%	0%	-14%
Daphnia								
Live	10	10	20	7	23	11	43	
Dead	0	0	0	2	3	5	10	
Mortality	0%	0%	0%	22%	12%	31%	19%	19%
Holopedium								
Live	-	3	3	-	5	-	5	
Dead	-	1	1	-	0	-	0	
Mortality	-	25%	25%	-	0%	-	0%	-25%
Ceriodaphnia								
Live	-	-	-	1	-	1	2	
Dead	-	-	-	0	-	0	0	
Mortality	-	-	-	0%	-	0%	0%	
Polyphemus								
Live	1	-	1	-	-	-	-	
Dead	0	-	0	-	-	-	-	
Mortality	0%	-	0%					
Harpactacoids								
Live	-	-	-	-	-	0	0	
Dead	-	-	-	-	-	1	1	
Mortality	-	-	-	-	-	∞	∞	
Epischura								
Live	-	-	-	-	-	2	2	
Dead	-	-	-	-	-	0	0	
Mortality	-	-	-	-	-	0%	0%	

Table 23 gives the mortality of Zooplankton for each species collected on October 2, 1971 at Point Beach Power Plant.

Table 24 lists species counts obtained on June 6 and June 9 at Bailly and Michigan City respectively.

TABLE 24. Zooplankton counts; bag experiments, June 1971.

Species	IP1	IP2	IA1	IA2	OP1	OP2	OA1	OA2
				Bailly Plant 6 VI 71				
Bosmina	0	1	1	-	-	3	0	-
Cyclopoids	0	2	10	-	-	19	3	-
Diaptomids	0	0	14	-	-	3	3	-
Insects	10	8	0	-	-	0	2	-
				Michigan City Plant 9 VI 71				
Bosmina	4	-	4	8	22	14	22	6
Cyclopoids	25	-	13	15	97	80	61	77
Diaptomids	16	-	1	8	40	31	15	28
Holopedium	0	-	1	0	0	0	0	0
Asplanchna	0	-	0	0	0	0	0	2
Rotifers	0	-	0	0	0	1	0	0
Insects	4	-	1	1	1	0	3	0

Measurement of the Three Dimensional Extents of Existing Warm Water Plumes

The temperature profiles were measured with a recording electric bathythermograph developed at the Great Lakes Research Division. A detailed description of the design and calibration is given in The pressure sensor when critically damped has a response time of less than 250 micro seconds; that is, it takes less than 0.75 milli-seconds for the pressure sensor to indicate 95% of the correct change when subjected to an abrupt change in depth. The temperature sensor's responses for 95% of a step change is less than five seconds. The accuracy of the temperature sensor is $\pm$ 0.15°C from -5°C to 45°C. The pressure sensor has a guaranteed hysterisis of less than 0.25% full scale output, or roughly six inches in depth. The repeatibility is stated to be 0.1% fullscale output, or less than three inches of error. Considering the surface wave motion these figures are very acceptable.

When lowering and raising the BT, the depth was changed approximately one foot at a time, and sufficient time was allowed for the temperature to attain equilibrium before further lowering and raising of the sensor. A YSI Thermistor (Model 401) and Indicator (Model 44) was used to monitor the surface temperature of the stations from the ZODIAC. A similar thermistor and indicator with YSI Model 80 recorder was used to provide a continuous record of water temperature at two-foot depth on board R/V MYSIS which was anchored outside and upstream of the plume to check on the diurnal change in water temperature throughout the duration of the survey. When the ten-minute averages show a steady change, indicating diurnal warming, a least-square linear regression was calculated and a temperature adjustment with time was applied to the surface temperature.

A precise grid was not predetermined for the station locations since the direction of the plume is not known before hand. The station locations generally follow the diffusion pattern of a continuous point source. A drogue was first released from the center of the outfall and the path of the drogue travel is assumed to be the center of the effluent plume. A temperature profile was recorded by the electric bathythermograph at the center of the outfall and along the plume axis. The distances between stations along the axis are pseudo-logarithmically spaced with the first stations about two to three hundred feet apart. Three to four more transects were made forming a conic section about the center axis of the plume. At each station the small boat was anchored and the position of the station fixed by triangulation to known landmarks using a sextant.

The data of the 1971 surveys are given in Table 25 and plotted in figures 7 through 33.

It seems quite evident from these temperature cross-sections and surface plots that the heated body of water rises rapidly to the surface immediately after being discharged into the lake. From a temperature standpoint, it is hardly distinguishable from the ambient water at about two thousand feet from the point of discharge.

TABLE 25. Station temperature profiles; summary of plume measurements, 1971.

Stn. no.	Time	Sfc. temp adj.	Sfc. temp C°	1 ft temp C°	2 ft temp C°	4 ft temp C°	8 ft temp C°	Bottom temp C°	Bottom depth ft.
				Bailly Power Plant 6 VI 71 T adj. = (10:13-t) 0·0066					
1	0905	+0.4	17.8	17.8	17.8	17.6	17.2	17.2	14.5
2	15	+0.4	20.8	20.8	20.8	20.8	20.8	20.8	10.0
3	28	+0.3	20.7	20.7	20.7	20.7	20.7	20.7	7.5
4	30	+0.3	19.3	19.3	18.8	18.7	-	18.7	7.0
5	37	+0.2	18.8	18.8	18.7	18.1	17.9	17.8	11.0
6	41	+0.2	18.5	18.5	18.4	17.9	17.6	17.6	12.5
7	45	+0.2	18.2	18.2	18.1	17.8	17.5	17.3	17.5
8	49	+0.2	18.2	18.1	18.0	17.6	17.5	17.5	17.0
9	58	+0.1	17.9	17.9	17.8	17.6	17.4	16.9	17.5
10	1003	+0.1	19.5	19.4	19.2	18.8	18.3	18.3	10.0
11	09	+0.0	19.9	19.4	19.2	18.9	18.7	18.5	12.5
12	13	0.0	19.0	18.9	18.8	18.4	18.0	17.8	16.5
13	18	0.0	19.2	19.1	18.9	18.4	18.2	18.0	12.5
14	23	-0.1	19.2	19.0	18.4	17.8	17.5	17.5	18.5
15	27	-0.1	18.5	18.3	18.3	17.7	17.4	17.4	22.5
16	32	-0.1	18.7	18.6	18.5	18.1	17.9	17.6	14.0
17	38	-0.2	18.3	18.0	17.8	17.5	17.3	17.2	17.5
18	41	-0.2	19.2	18.8	18.4	18.0	17.9	17.9	16.0
19	45	-0.2	19.9	19.9	19.7	19.2	18.5	18.4	10.5
20	50	-0.2	19.1	19.1	19.0	18.6	18.1	17.9	12.5
21	57	-0.3	18.9	18.7	18.6	18.5	18.0	17.9	13.5
22	1101	-0.3	19.2	19.1	18.9	18.6		18.6	7.0
23	05	-0.3	19.7	19.7	19.6	19.5	18.8	18.8	9.5
24	09	-0.4	19.0	18.9	18.8	18.4	18.0	18.0	8.5
25	12	-0.4	18.2	18.0	17.9	17.6	17.5	17.5	9.5
26	15	-0.4	17.8	17.6	17.5	17.3		17.3	5.5
27	19	-0.4	19.0	18.8	18.2	18.0		18.0	4.5
28	22	-0.5	19.2	19.1	18.9	18.6		17.9	6.0
				Michigan City Plant 9 VI 71					
1	none								
2	0906		21.1	21.1	21.1	21.1		18.1	7.5
3	10		17.7	17.5	17.3	16.5	16.4	16.4	8
4	13		16.3	16.3	16.1	15.4	15.2	15.2	10
5	17		15.7	15.7	15.7	15.4	15.0	15.0	14
6	21		15.3	15.3	15.2	15.2	15.1	14.7	19
7	26		15.5	15.5	15.4	15.3	15.1	14.8	25

continued---

TABLE 25 continued

Stn. no.	Time	Sfc. temp adj.	Sfc. temp C°	1 ft temp C°	2 ft temp C°	4 ft temp C°	8 ft temp C°	Bottom temp C°	Bottom depth ft.
8	0931		16.0	15.9	15.8	15.5	15.2	15.0	19.5
9	36		17.0	16.8	16.5	15.9	15.6	15.5	14
10	40		18.1	18.0	17.4	16.2	16.0	16.0	12.5
11	45		19.0	18.9	18.7	17.2	16.6	16.6	9
12	50		18.5	16.9	16.1	15.9	15.8	15.8	9
13	54		15.0	15.0	15.0	15.0	14.9	14.8	14
14	58		17.0	16.5	15.5	15.2	15.0	15.0	13.5
15	1005		16.0	16.0	15.9	15.6	15.2	15.2	18.5
16	10		15.3	15.3	15.3	15.3	15.3	14.8	22
17	16		15.2	15.2	15.2	15.2	15.0	14.9	11
18	20		15.1	15.1	15.1	15.1	14.8	14.8	9
19	24		16.8	16.3	15.3	15.0		15.0	6.5
20	27		15.2	15.1	15.0	15.0		15.0	4
21	31		15.1	15.1	15.1			15.1	3
22	35		16.5	16.5	16.3	16.1	15.8	15.4	20
23	39		15.4	15.4	15.3	15.3	15.3	15.3	16
24	44		16.5	16.6	16.7	16.9	16.8	16.1	17
25	49		16.2	16.2	16.2	16.1	15.9	15.6	10

Point Beach Nuclear Plant
14 VI 71

Stn. no.	Time	Sfc. temp adj.	Sfc. temp C°	1 ft temp C°	2 ft temp C°	4 ft temp C°	8 ft temp C°	Bottom temp C°	Bottom depth ft.
1	1531		19.0	19.0	19.0	19.0	19.0	17.8	12.6
2	37		16.2	16.2	16.2	16.2	16.2	15.9	10.5
3	41		15.0	14.9	14.8	14.2	12.5	12.2	12
4	46		14.4	14.2	14.0	12.8	11.9	11.8	10.5
5	52		13.2	13.0	12.8	11.8	10.8	10.8	13.5
6	56		15.7	15.0	14.2	13.5	12.3	12.2	9.7
7	1602		15.3	15.2	14.8	13.5	12.0	11.8	10.5
8	06		16.0	15.9	15.8	13.8	11.8	11.6	9
9	10		16.3	16.3	16.3	16.1		15.4	6.5
10	14		17.3	17.2	17.0	16.8	15.6	14.6	9.5
11	19		16.6	16.4	16.2	15.7	14.0	13.6	11
12	23		13.5	13.4	13.3	12.8	11.6	11.4	16
13	28		13.0	12.8	12.6	11.6	11.1	10.8	21.5
14	34		13.2	13.1	13.0	11.4	11.0	10.8	24
15	38		13.2	13.0	12.8	11.4	11.1	11.0	18.5
16	42		13.2	13.0	12.9	11.8	11.3	11.2	14.0
17	46		14.4	14.2	13.9	13.2	11.8	11.8	10
18	50		17.5	17.5	17.5	17.5	17.3	17.2	11.5
19	55		12.0	11.8	11.6	11.4		11.3	6
20	58		11.9	11.9	11.8	11.6	11.5	11.5	8.5

continued---

TABLE 25 continued

Stn. no.	Time	Sfc. temp adj.	Sfc. temp C°	1 ft temp C°	2 ft temp C°	4 ft temp C°	8 ft temp C°	Bottom temp C°	Bottom depth ft.
21	1703		13.0	12.4	11.6	11.2	10.9	10.7	14.5
22	07		13.0	12.8	12.6	11.8	11.2	11.2	10
23	11		17.0	17.0	16.9	16.8		16.7	7.5
24	16		15.2	14.9	14.8	14.4	13.4	12.5	11.2
25	23		13.9	13.8	13.6	13.3	12.0	11.3	15
				15 VI 71					
1	1459		20.2	20.2	20.2	20.2	20.2	20.1	12.5
2	1504		18.7	18.7	18.6	18.4	17.6	15.3	11
3	08		16.2	16.1	15.9	15.2	13.4	12.6	14
4	13		16.0	15.9	15.7	15.0	13.3	12.8	16
5	18		15.0	14.9	14.8	14.5	13.2	12.5	18
6	25		15.2	15.0	14.8	14.4	13.7	12.1	23.5
7	32		14.8	14.7	14.6	14.5	14.0	12.4	27.5
8	38		16.2	15.8	15.6	15.2	14.4	12.6	18.5
9	44		15.3	15.2	15.0	14.7	14.6	14.5	10
10	49		15.2	15.1	15.0	14.4	14.0	14.0	9
11	53		15.2	15.0	14.8	14.4	13.7	13.5	10
12	58		15.0	14.9	14.6	13.5	13.1	11.8	14
13	1605		16.0	15.9	15.9	15.4	14.6	14.5	9
14	10		16.2	16.1	15.9	15.6	13.4	12.5	14.5
15	14		15.3	15.2	15.0	14.2	12.8	12.0	21
16	19		14.0	13.6	13.5	13.0	12.2	10.9	27
17	26		14.5	14.4	14.2	13.9	13.5	11.8	19
18	32		15.6	14.8	14.5	14.2	13.0	11.8	19
19	38		16.7	16.4	16.0	15.4	14.8	14.8	9
20	40		16.0	15.9	15.7	14.6	14.5	14.5	8
21	45		16.2	16.1	15.9	15.2	13.4	12.7	11
22	50		18.2	18.1	17.8	17.6	15.6	13.9	12
23	53		16.2	15.9	15.9	15.6	14.0	12.8	11
24	57		15.9	15.8	15.4	14.6	12.8	12.8	13
25	1700		16.2	16.0	15.8	15.2	13.3	12.5	14.5
26	10		15.4	15.4	15.2	15.0	13.0	12.2	19
				2 VI 71					
				T adj. = (1313-t) 0·007					
1	1230	+0.3	16.3	16.3	16.3	16.3	16.3	15.2	13.0
2	36	+0.3	11.8	11.6	11.4	11.0		8.4	6.5
3	43	+0.2	12.0	11.9	11.9	11.8	10.3	10.2	8.5
4	49	+0.2	11.5	11.0	10.6	10.1	9.5	7.5	13.0

continued---

TABLE 25 continued

Stn. no.	Time	Sfc. temp adj.	Sfc. temp C°	1 ft temp C°	2 ft temp C°	4 ft temp C°	8 ft temp C°	Bottom temp C°	Bottom depth ft.
5	56	+0.1	10.5	10.5	10.5	10.3	8.4	7.5	14.0
6	1302	0.0	10.0	9.9	9.9	9.6	9.0	8.4	14.0
7	06	0.0	10.0	9.9	9.9	9.9	9.5	9.4	11.0
8	13	0.0	12.5	12.3	12.0	11.8	10.0	9.9	10.0
9	19	0.0	15.6	15.4	15.3	15.0		13.6	7.0
10	26	-0.1	13.0	12.9	12.8	12.4	10.8	10.0	11.5
11	32	-0.1	12.1	12.0	12.0	11.4	9.0	7.2	12.5
12	38	-0.2	11.0	10.9	10.9	10.4	7.8	7.0	21.5
13	45	-0.2	11.5	11.4	11.0	9.8	7.4	7.1	23.5
14	51	-0.3	10.5	10.5	10.4	10.2	8.3	7.8	14.0
15	1400	-0.3	10.0	9.6	9.6	8.5	7.8	7.8	12.0

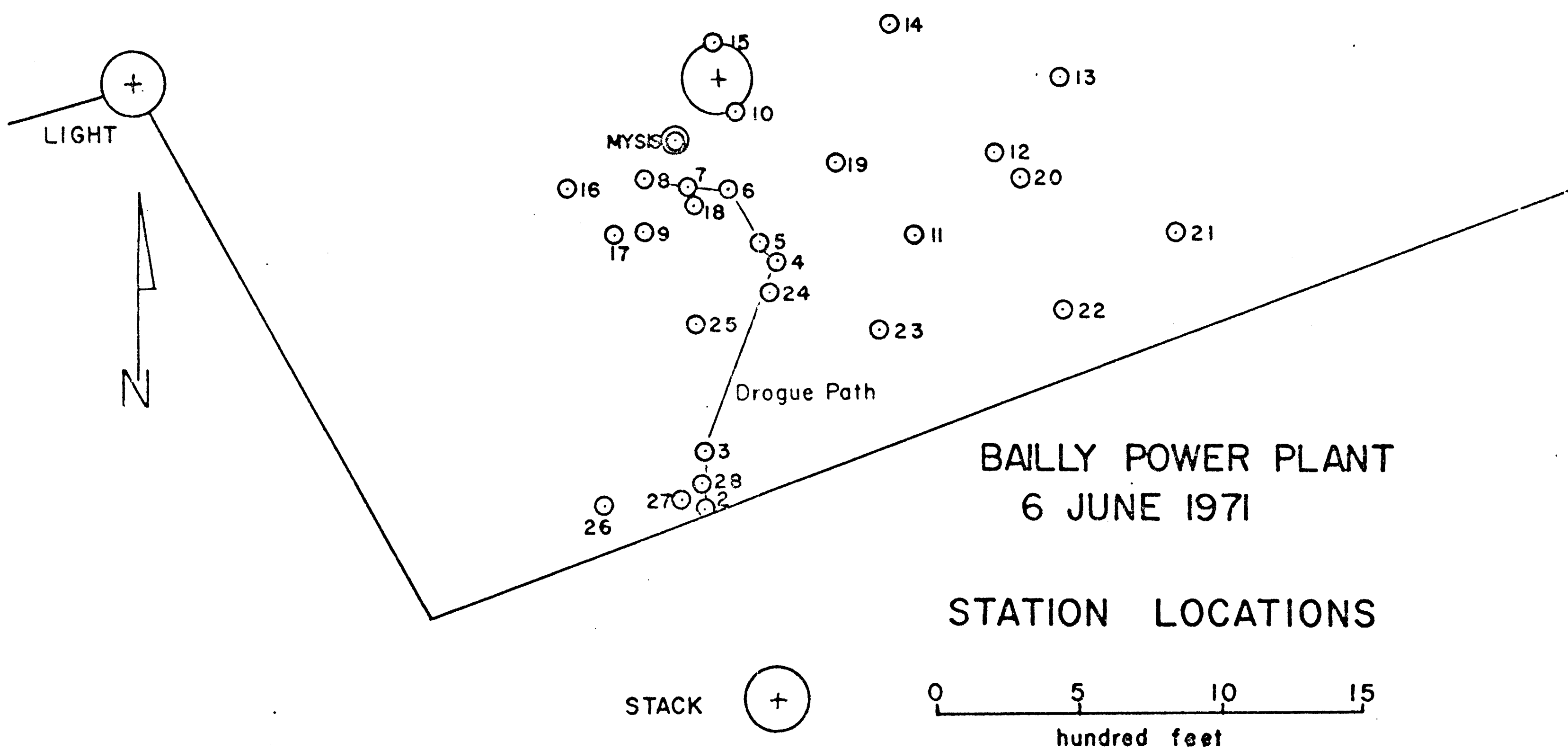


FIGURE 7. Bailly. B. T. Station Location Plot

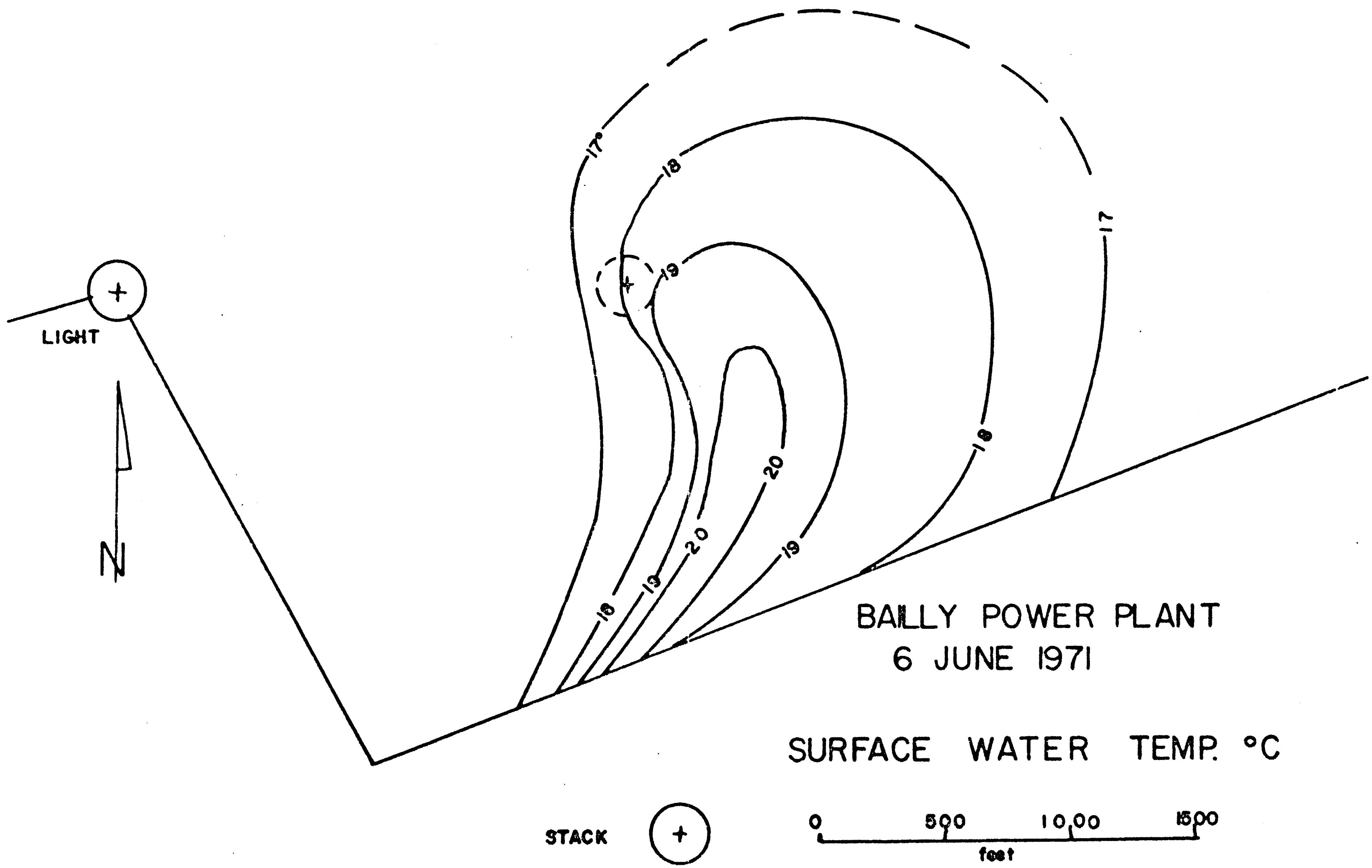


FIGURE 8. Bailly. Surface Temperature Contour

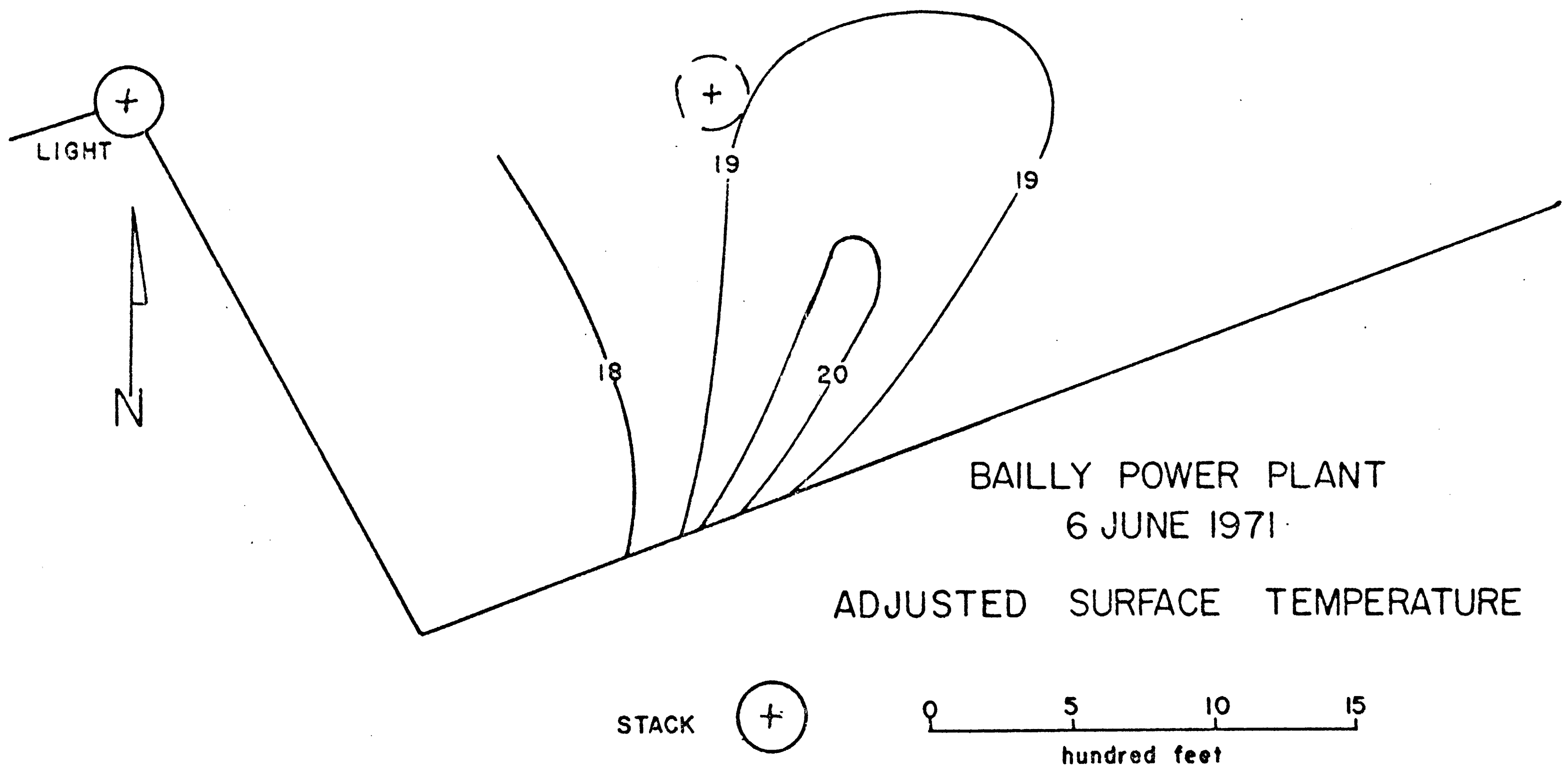


FIGURE 9. Bailly. Adjusted Surface Temperature Contour

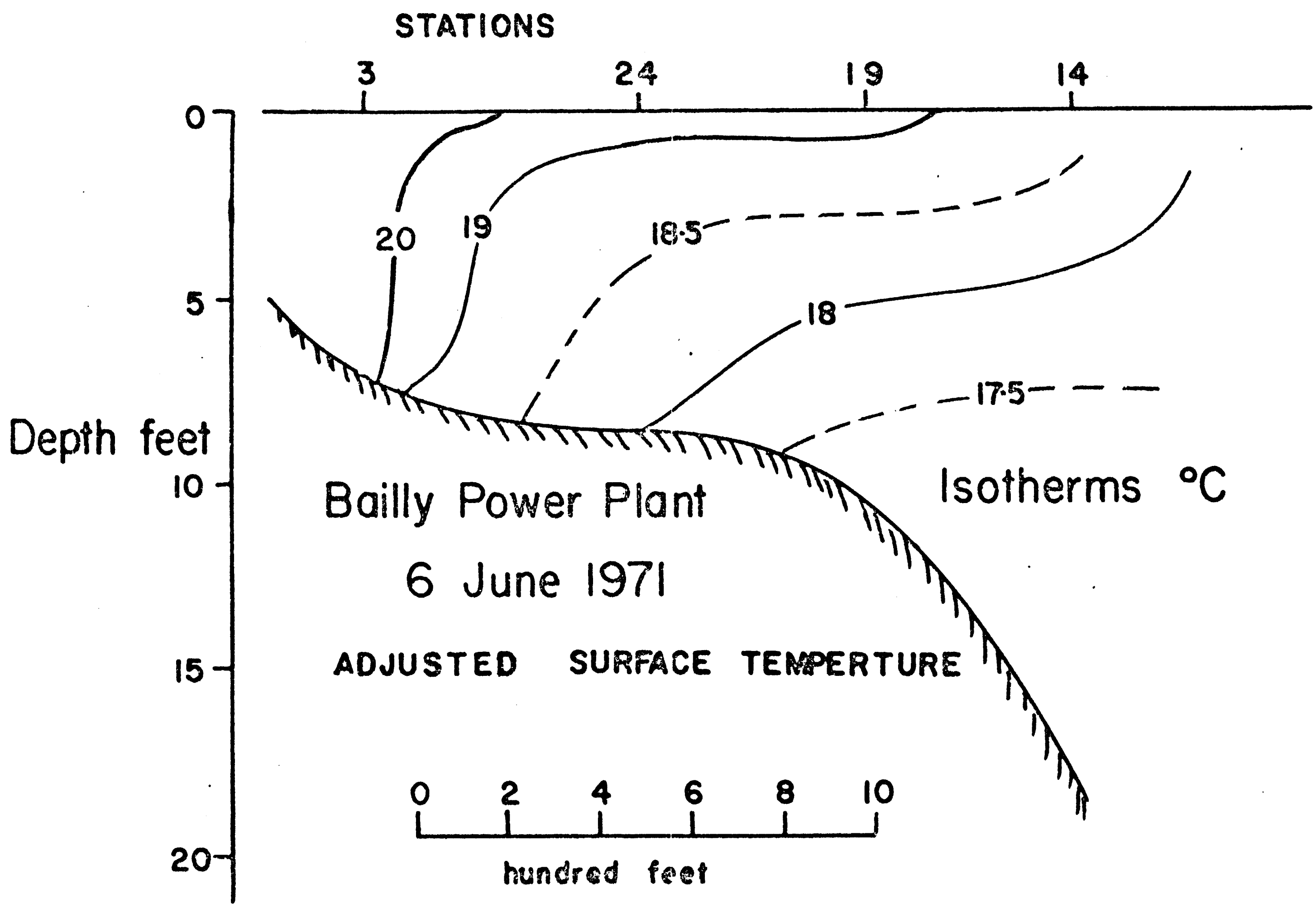


FIGURE 10. Bailly. Vertical Temperature Cross-section along Plume

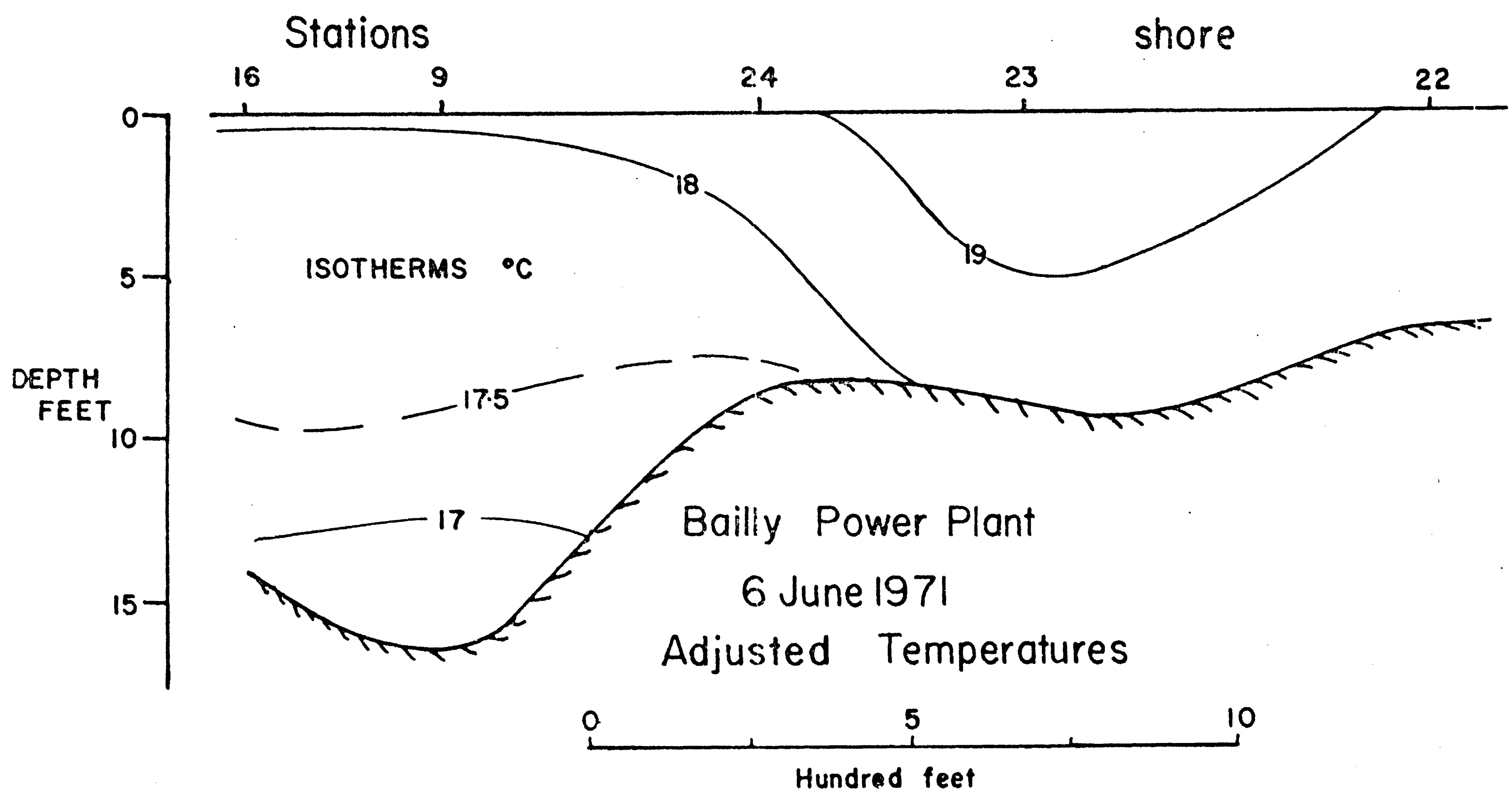


FIGURE 11. Bailly. Vertical Temperature Cross-section across Plume

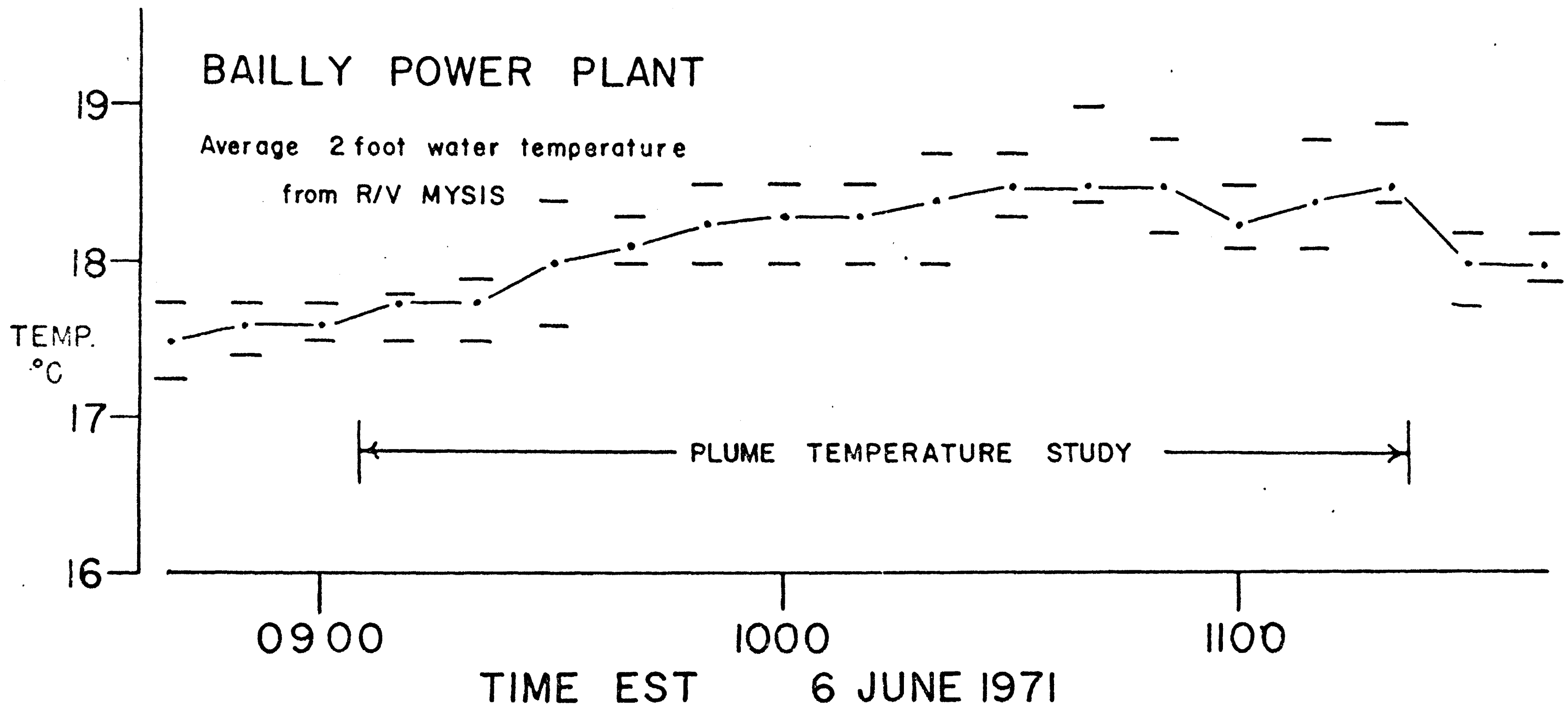


FIGURE 12. Bailly. Average (10 min. intervals) 2-foot Water Temperature Record from R/V MYSIS

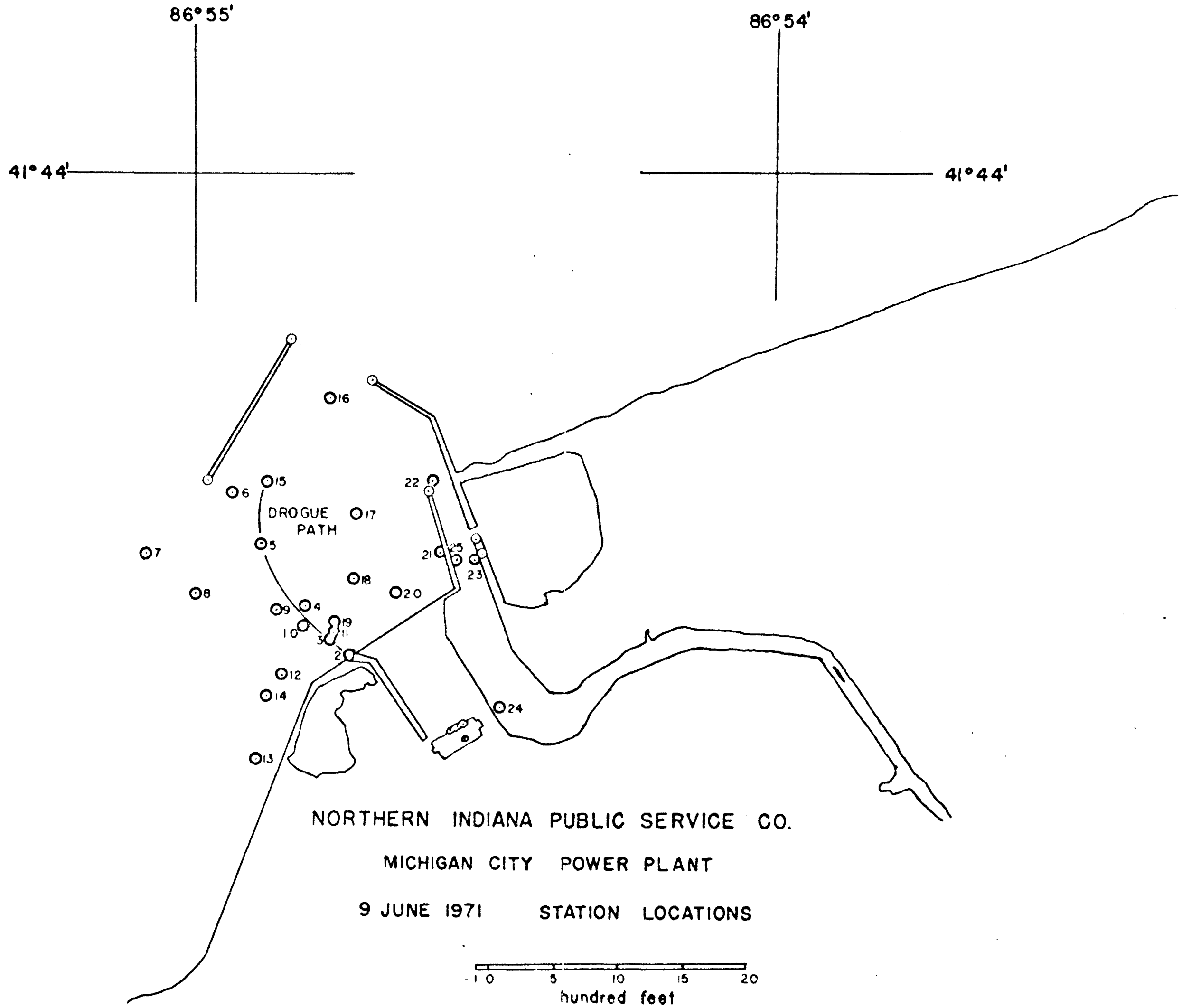


FIGURE 13. Michigan City. B. T. Station Location Plot

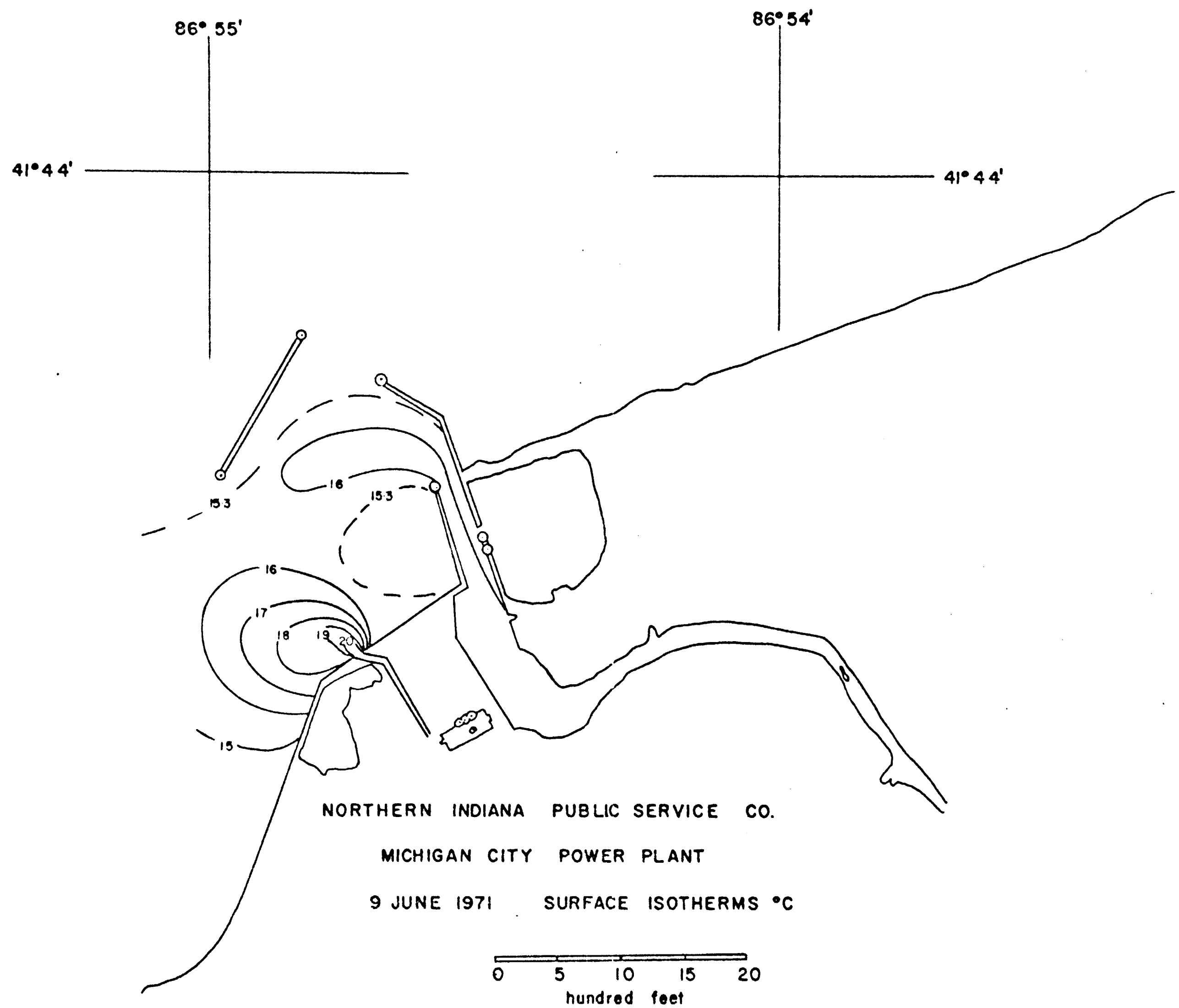


FIGURE 14. Michigan City. Surface Temperature Contour

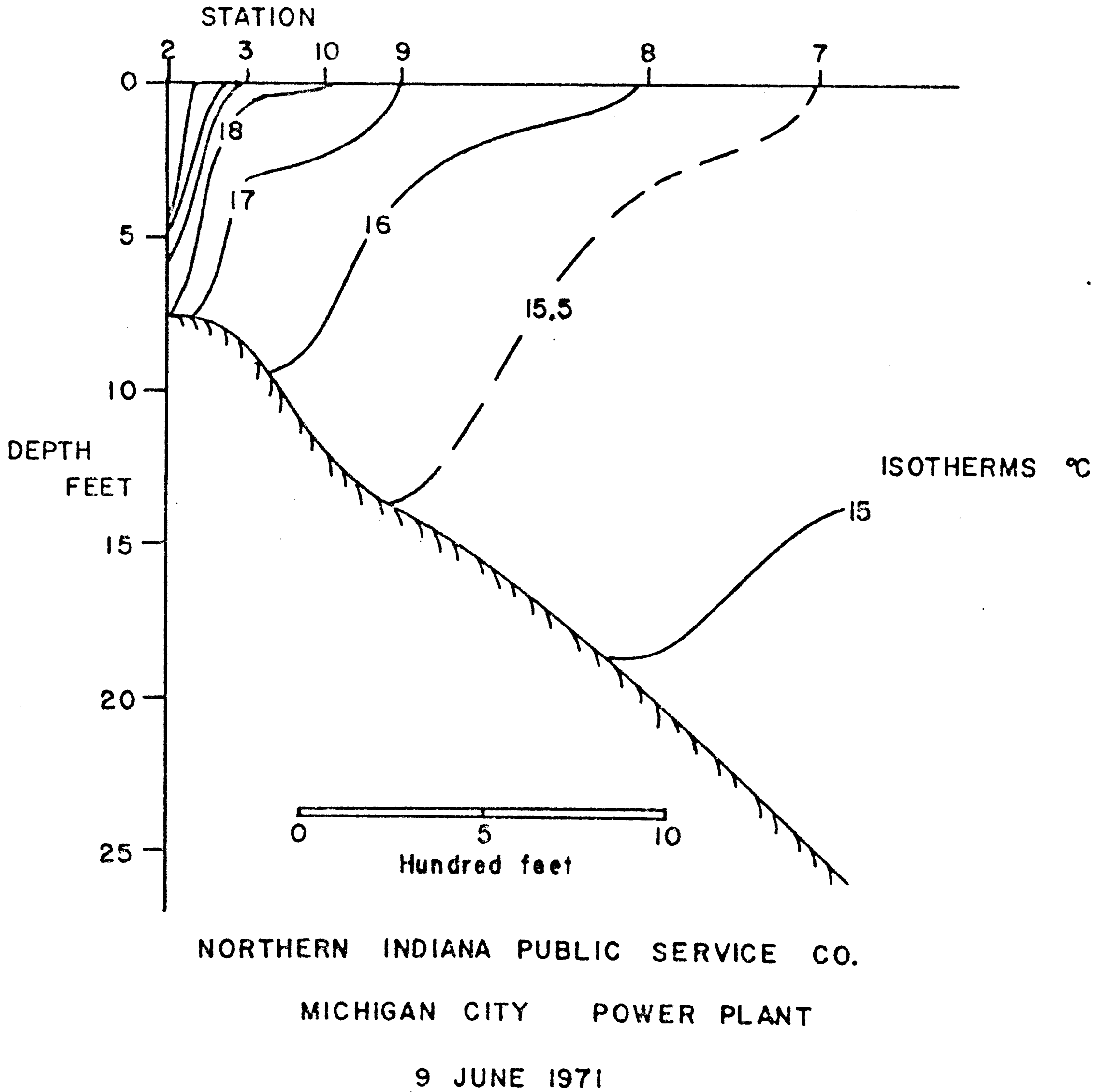
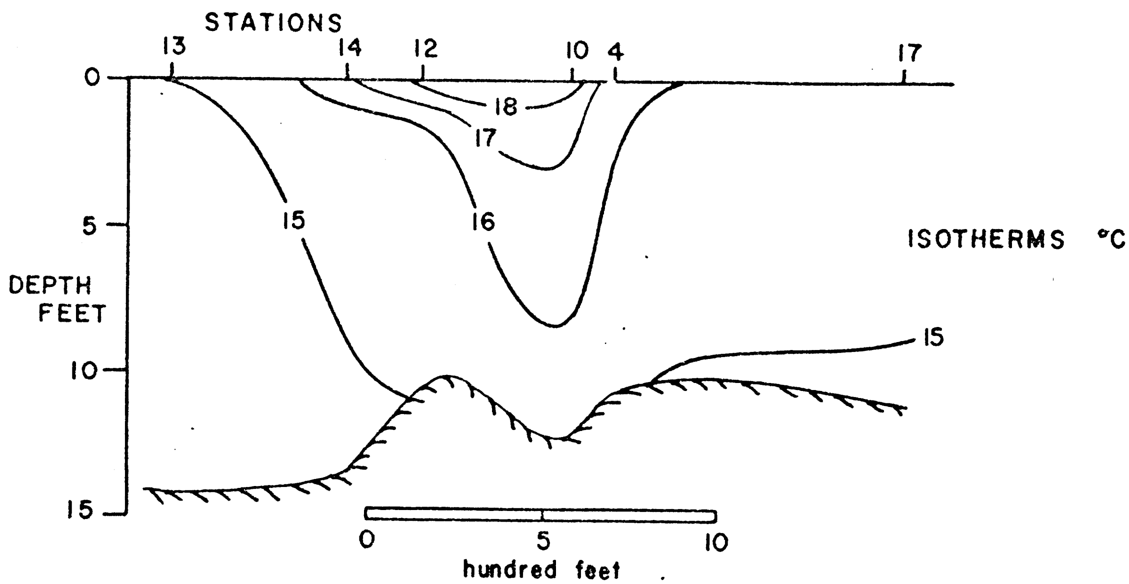


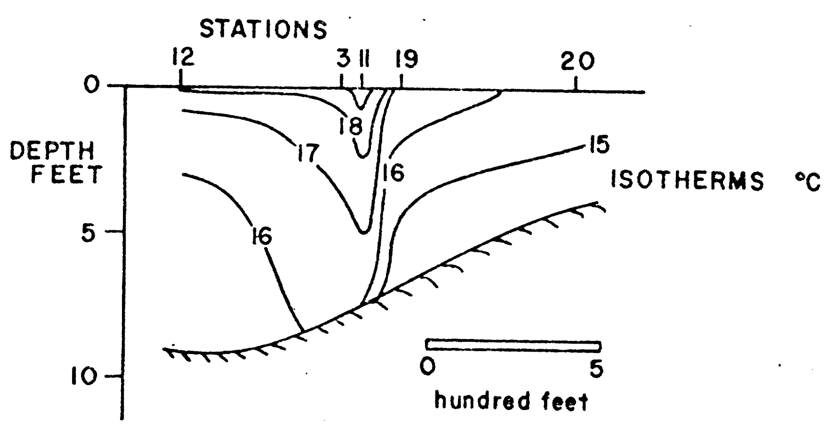
FIGURE 15. Michigan City. Vertical Temperature Cross-section along Plume



NORTHERN INDIANA PUBLIC SERVICE CO.

MICHIGAN CITY POWER PLANT

9 JUNE 1971



NORTHERN INDIANA PUBLIC SERVICE CO.

MICHIGAN CITY POWER PLANT

9 JUNE 1971

FIGURE 16. Michigan City. Vertical Temperature Cross-sections across Plume

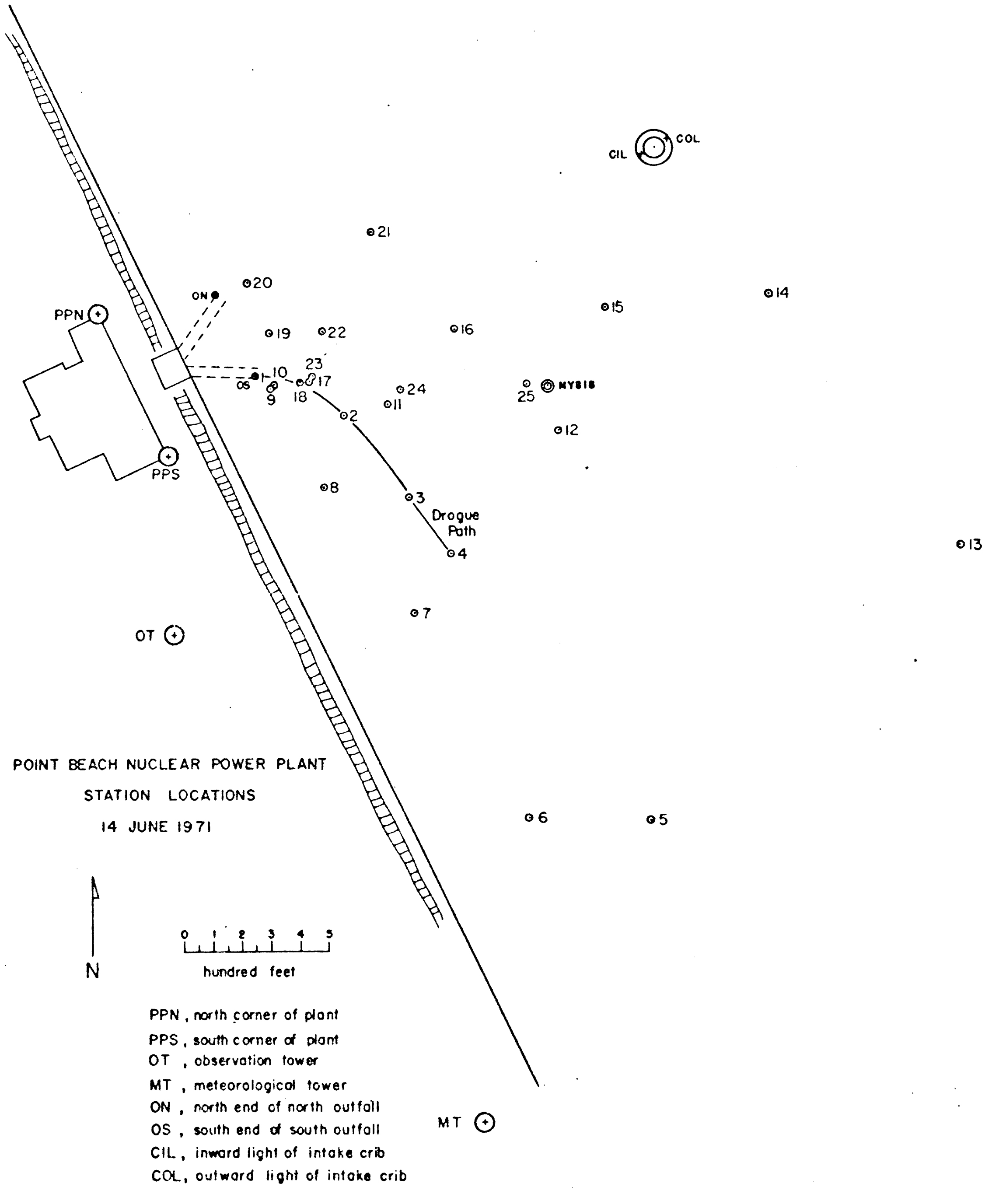


FIGURE 17. Point Beach, 14 VI 71. B. T. Station Location Plot

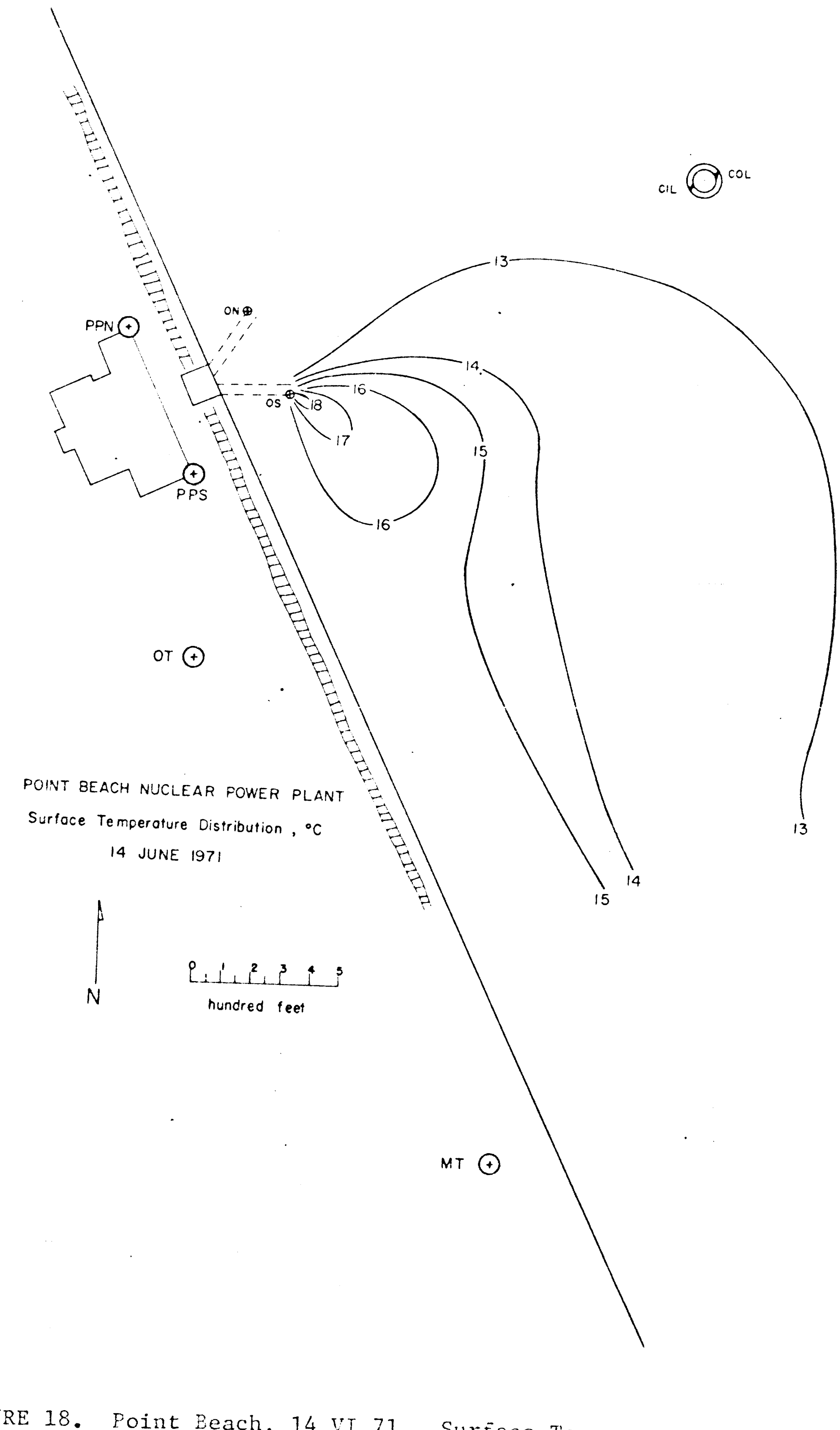


FIGURE 18. Point Beach, 14 VI 71. Surface Temperature Contour

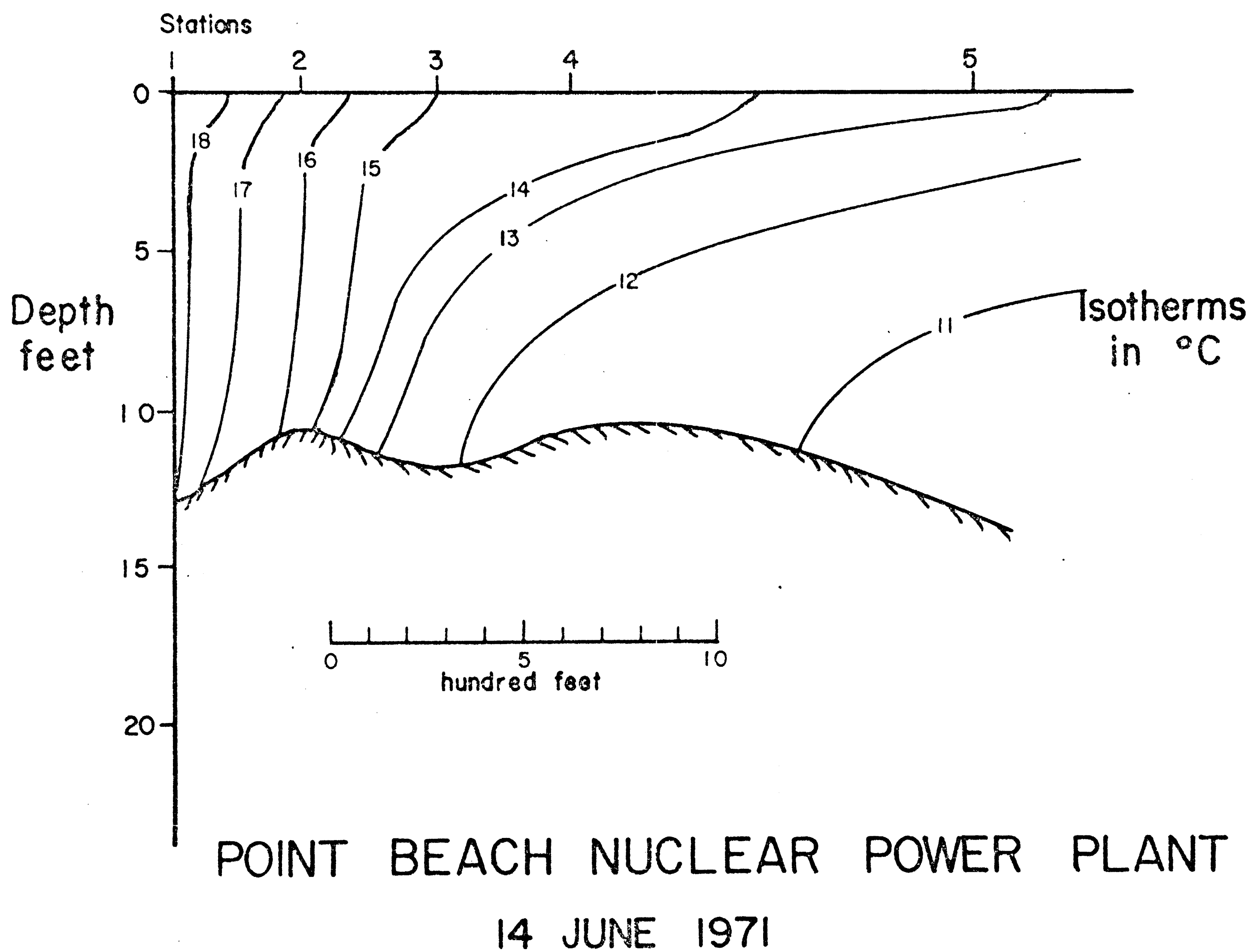


FIGURE 19. Point Beach, 14 VI 71. Vertical Temperature Cross-section along Plume

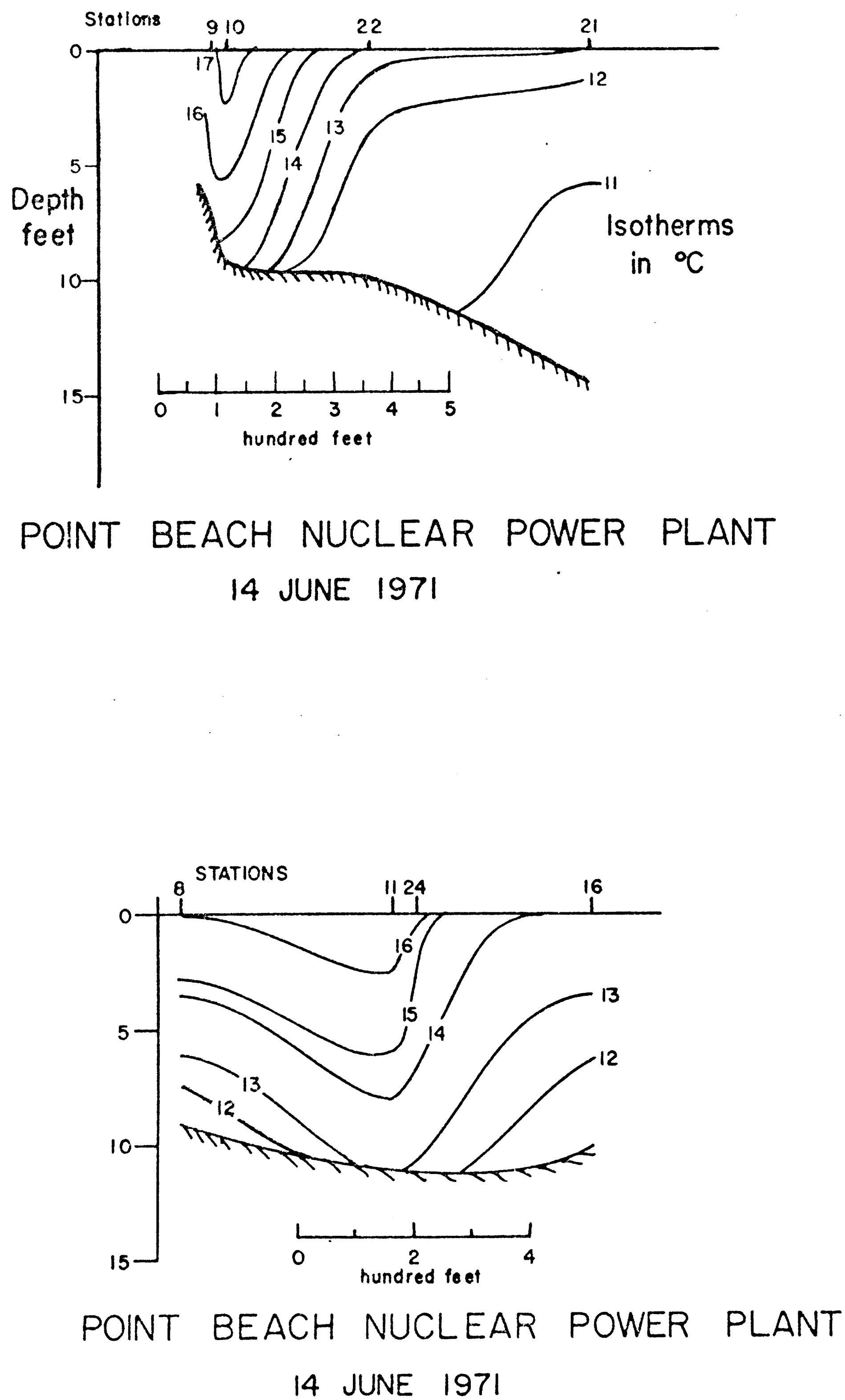


FIGURE 20. Point Beach, 14 VI 71. Vertical Temperature Cross-sections across Plume

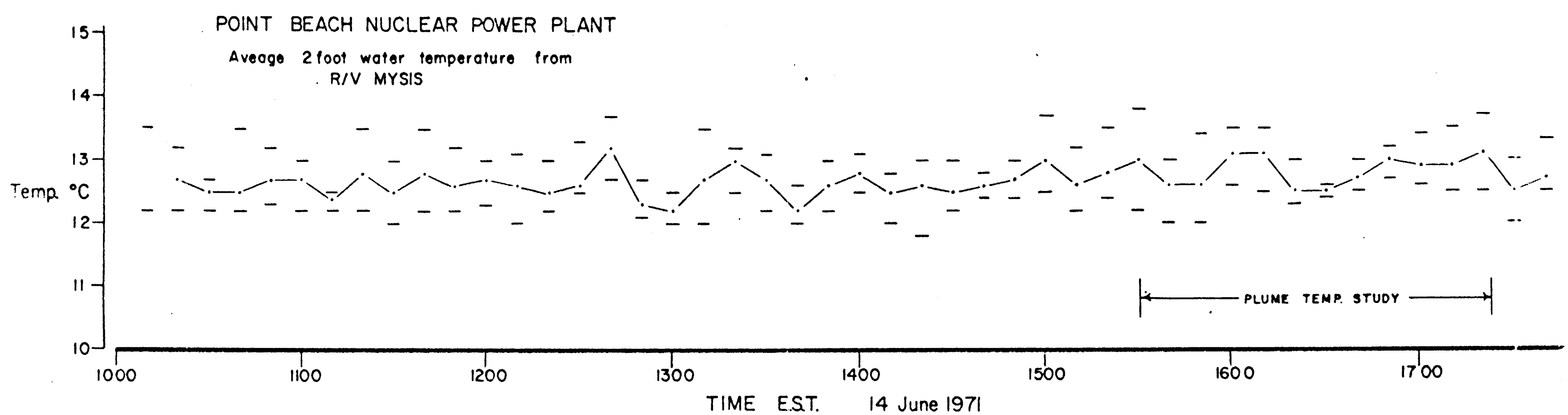


FIGURE 21. Point Beach, 14 VI 71. Average (10 min intervals) 2-foot Water Temperature Record from R/V MYSIS

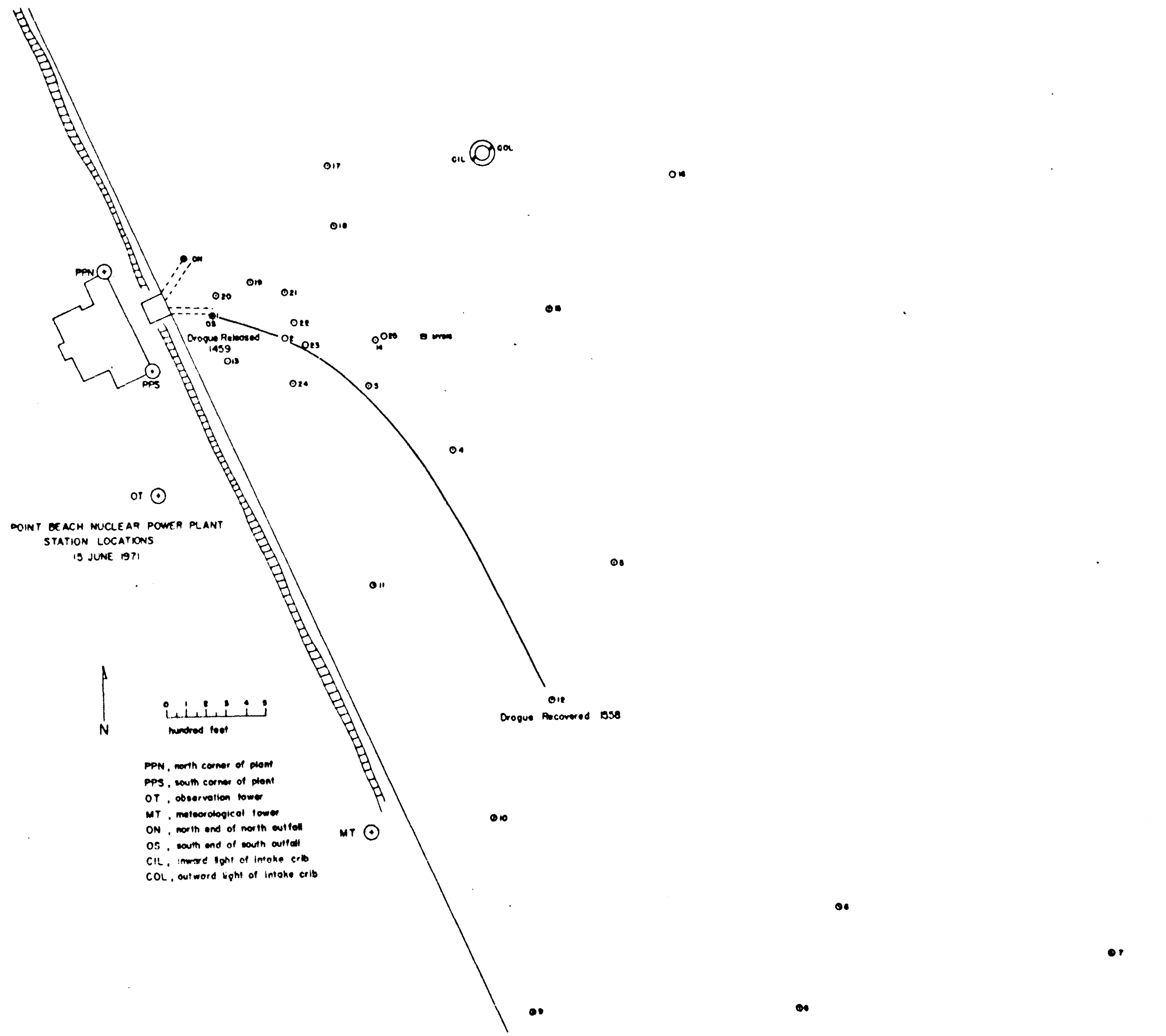


FIGURE 22. Point Beach, 15 VI 71. B. T. Station Location Plot

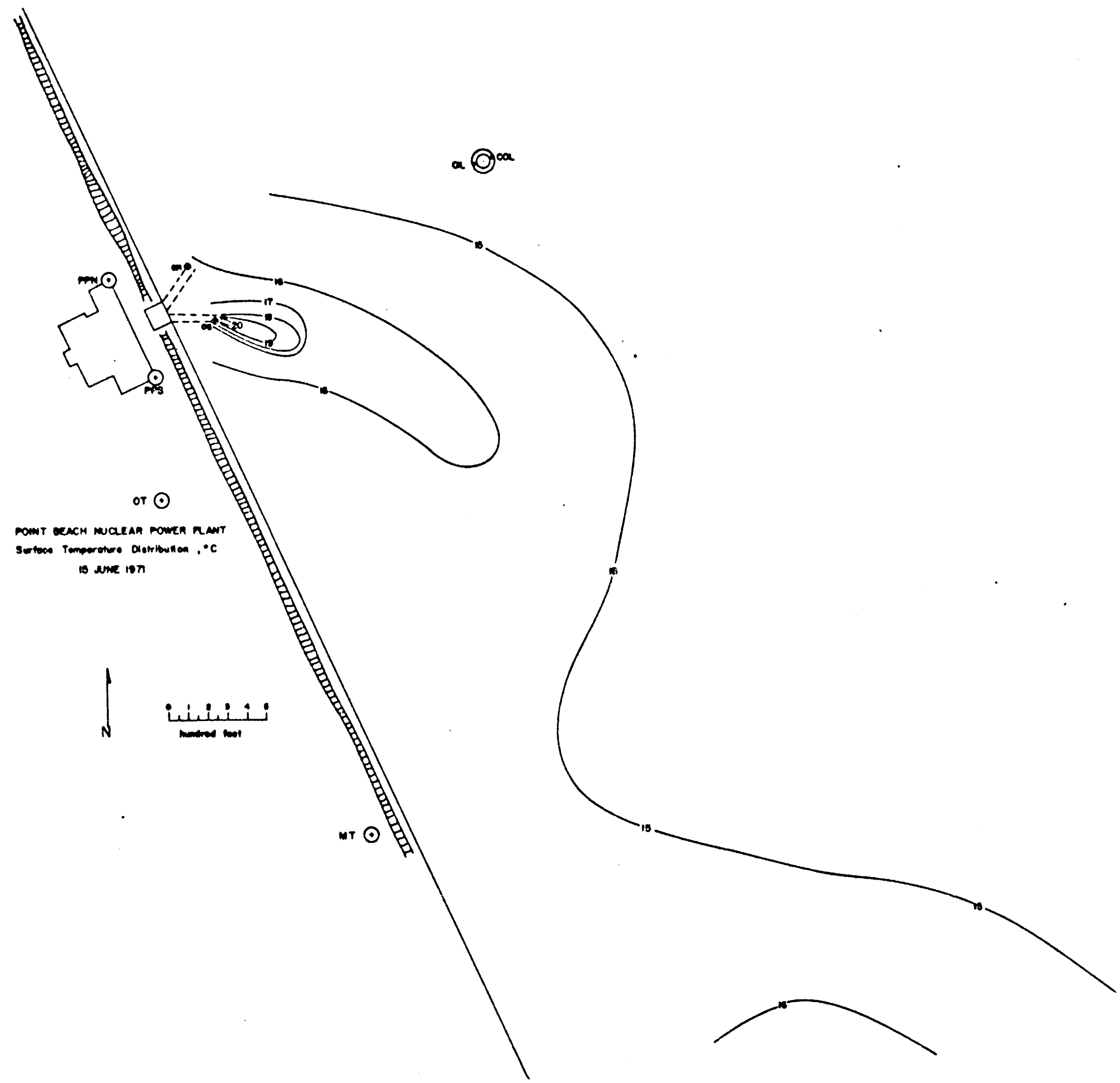


FIGURE 23. Point Beach, 15 VI 71. Surface Temperature Contour

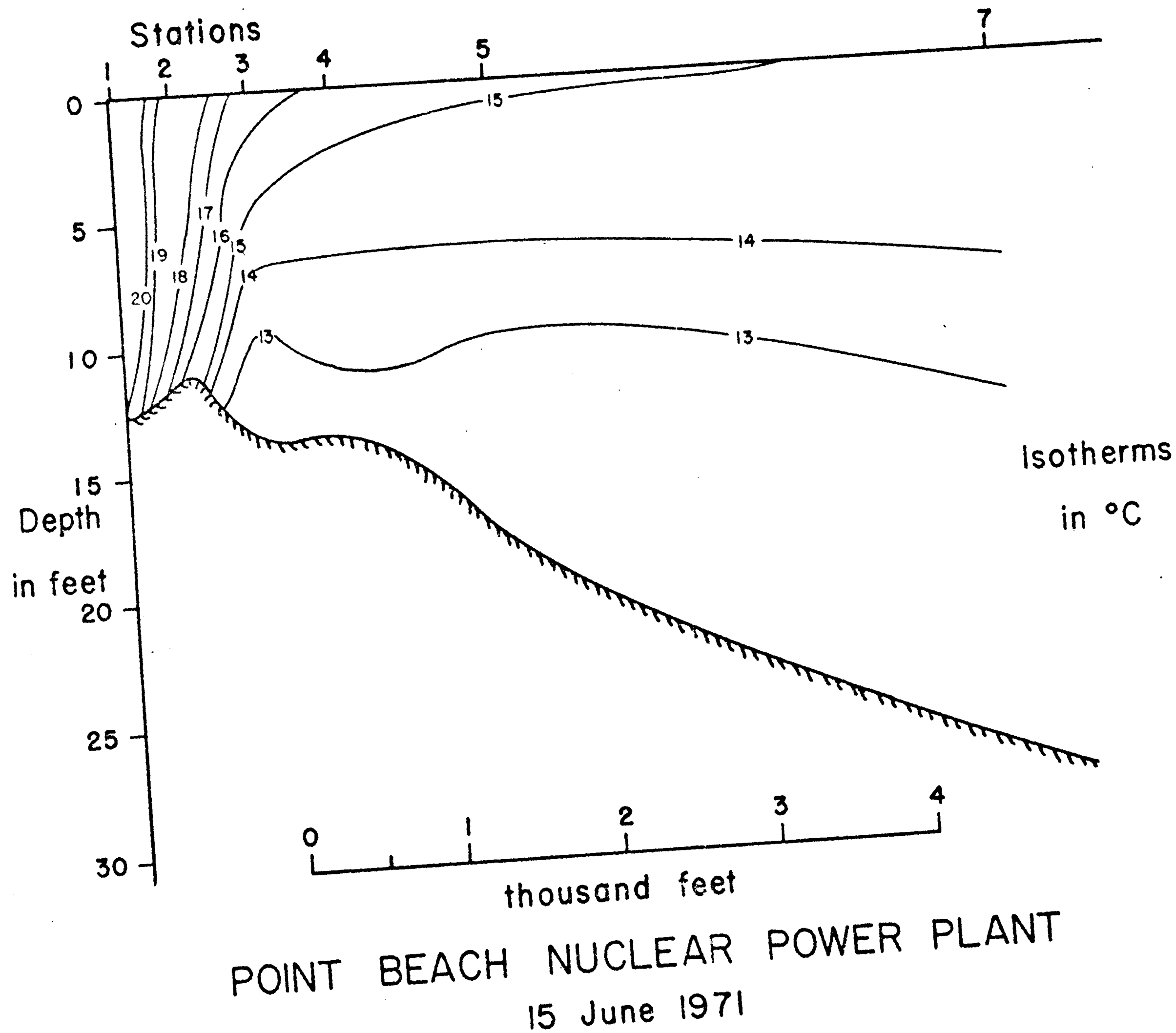


FIGURE 24. Point Beach, 15 VI 71. Vertical Temperature Cross-section along Plume

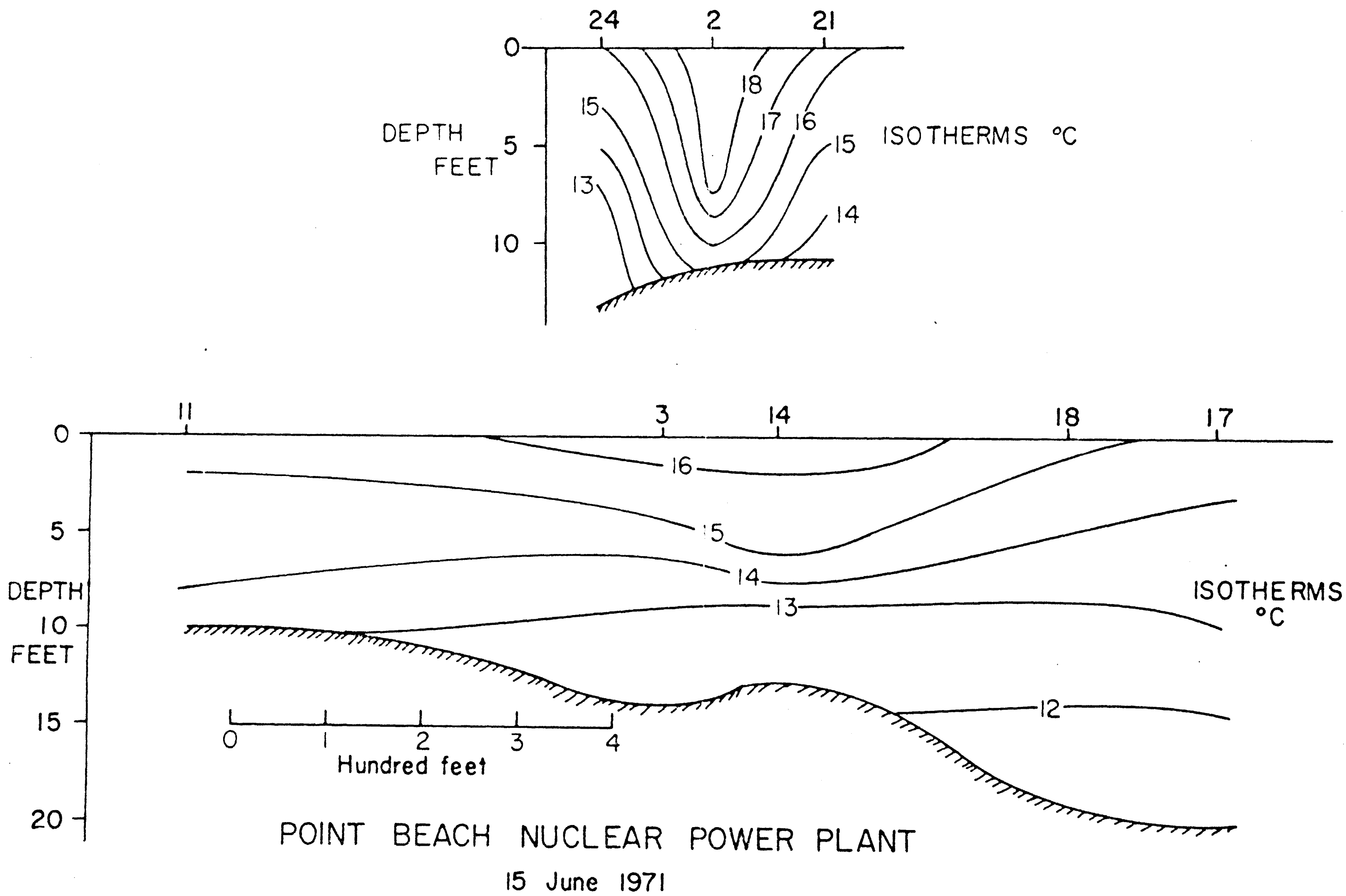


FIGURE 25. Point Beach, 15 VI 71. Vertical Temperature Cross-sections across Plume

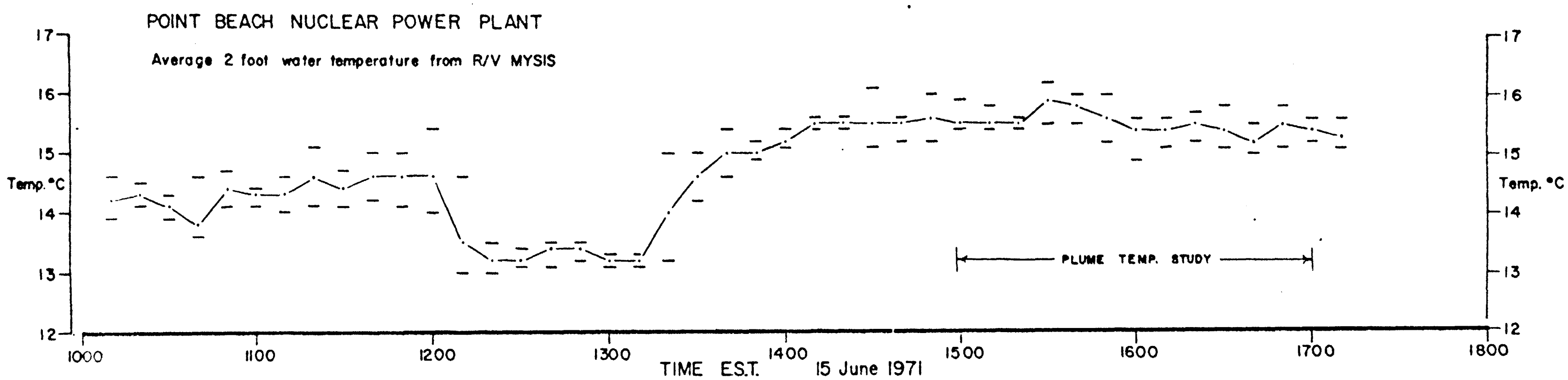


FIGURE 26. Point Beach, 15 VI 71. Average (10 min intervals) 2-foot Water Temperature Record from R/V MYSIS

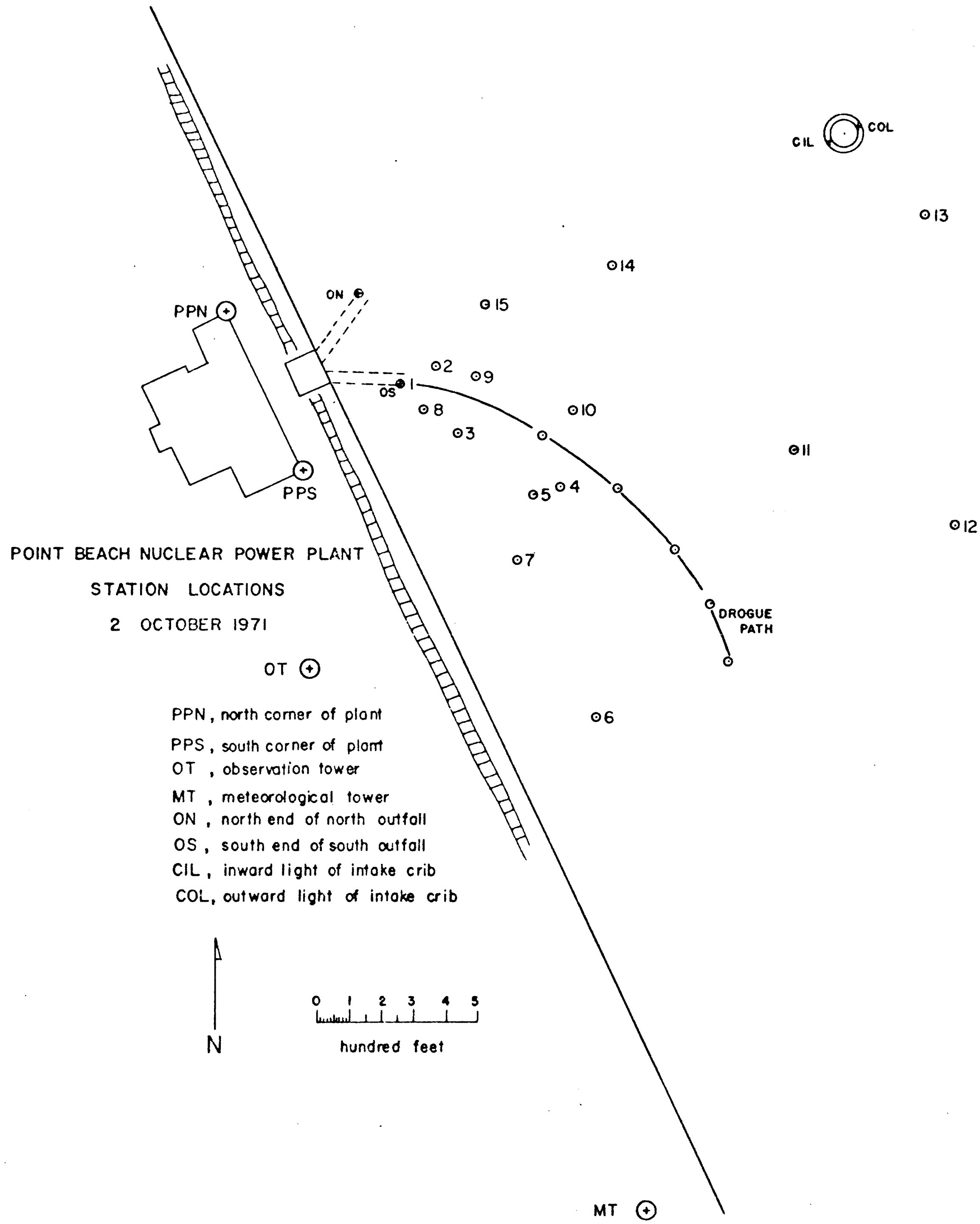


FIGURE 27. Point Beach, 2 X 71. B. T. Station Location Plot

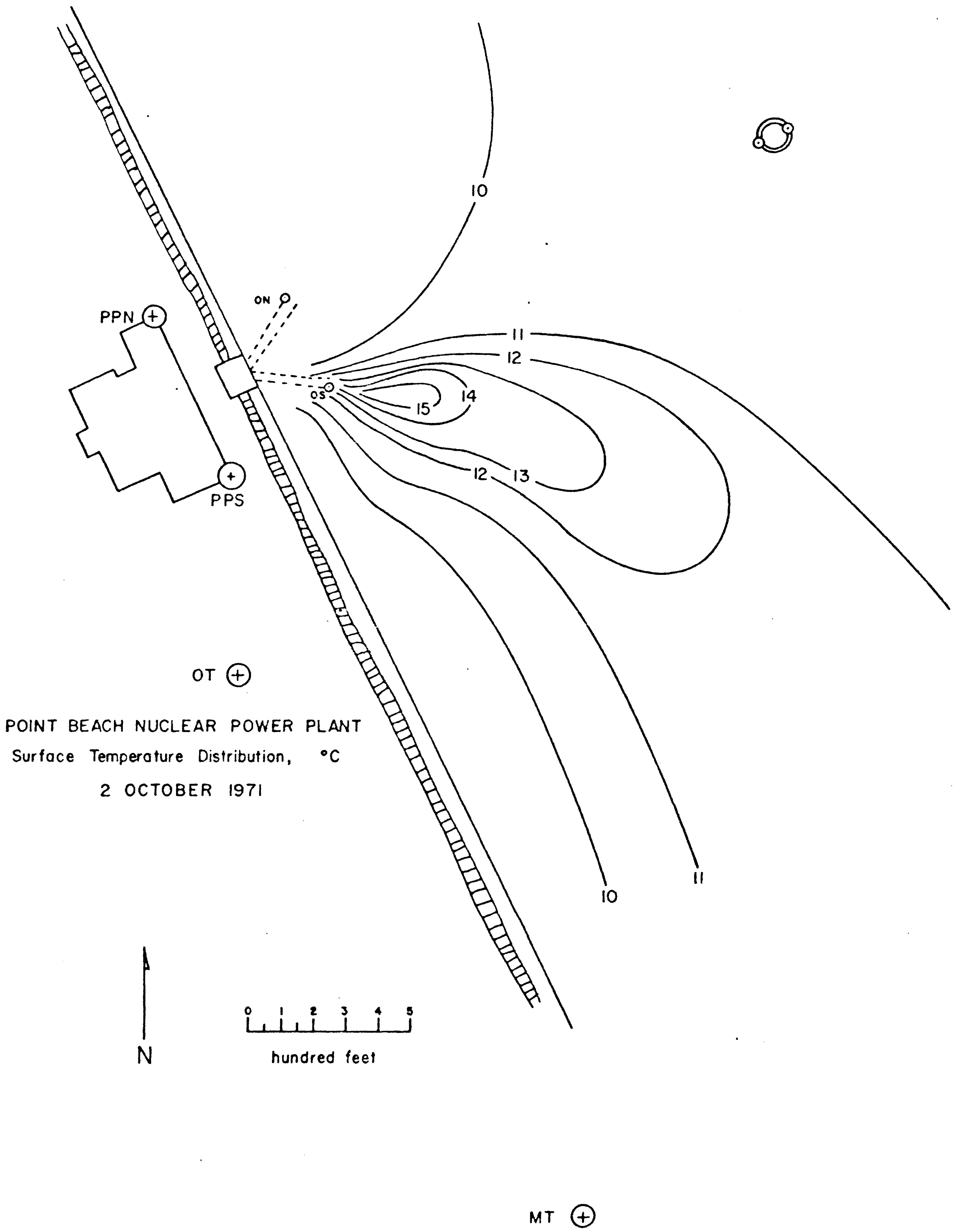


FIGURE 28. Point Beach, 2 X 71. Surface Temperature Contour

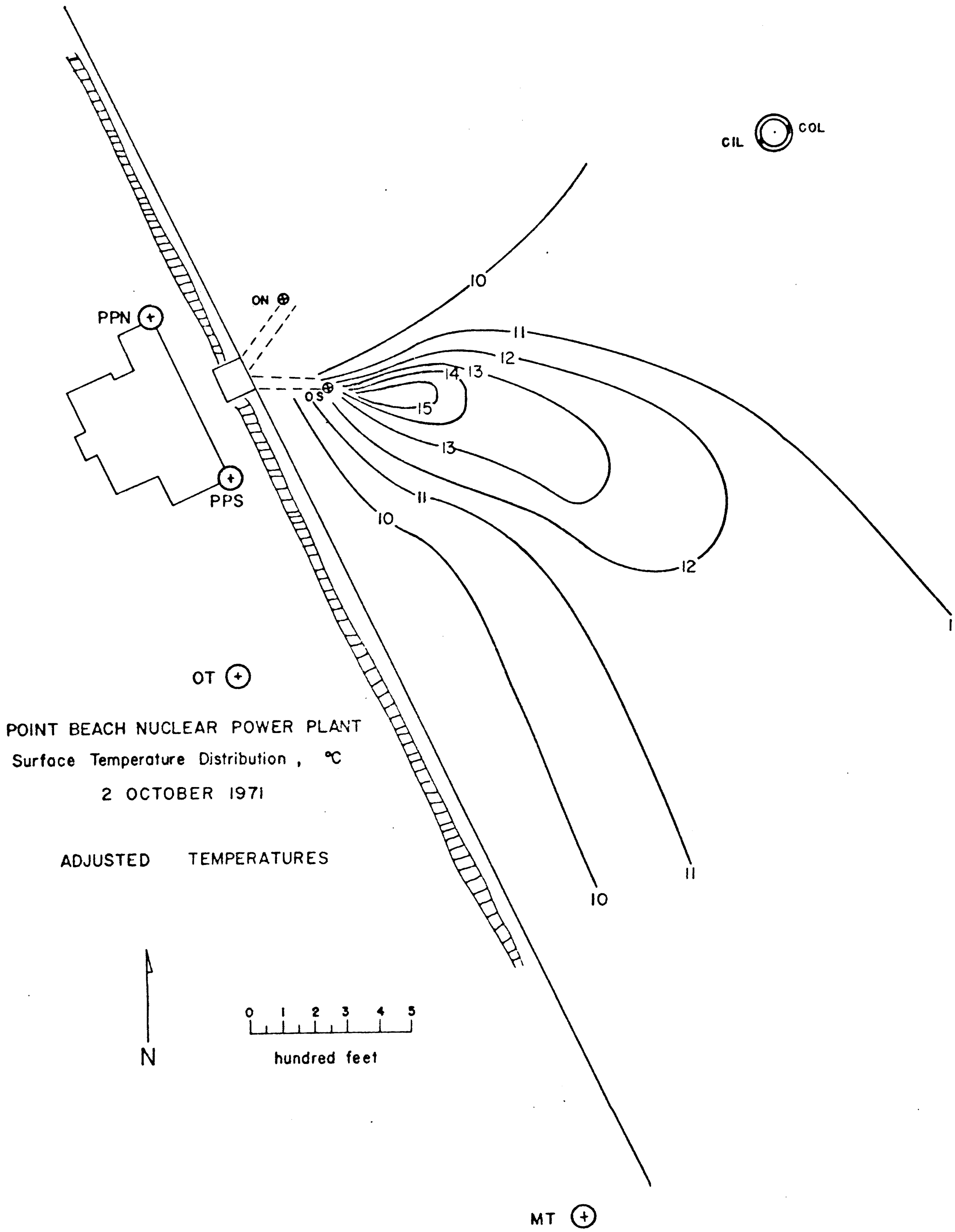


FIGURE 29. Point Beach, 2 X 71. Adjusted Surface Temperature Contour

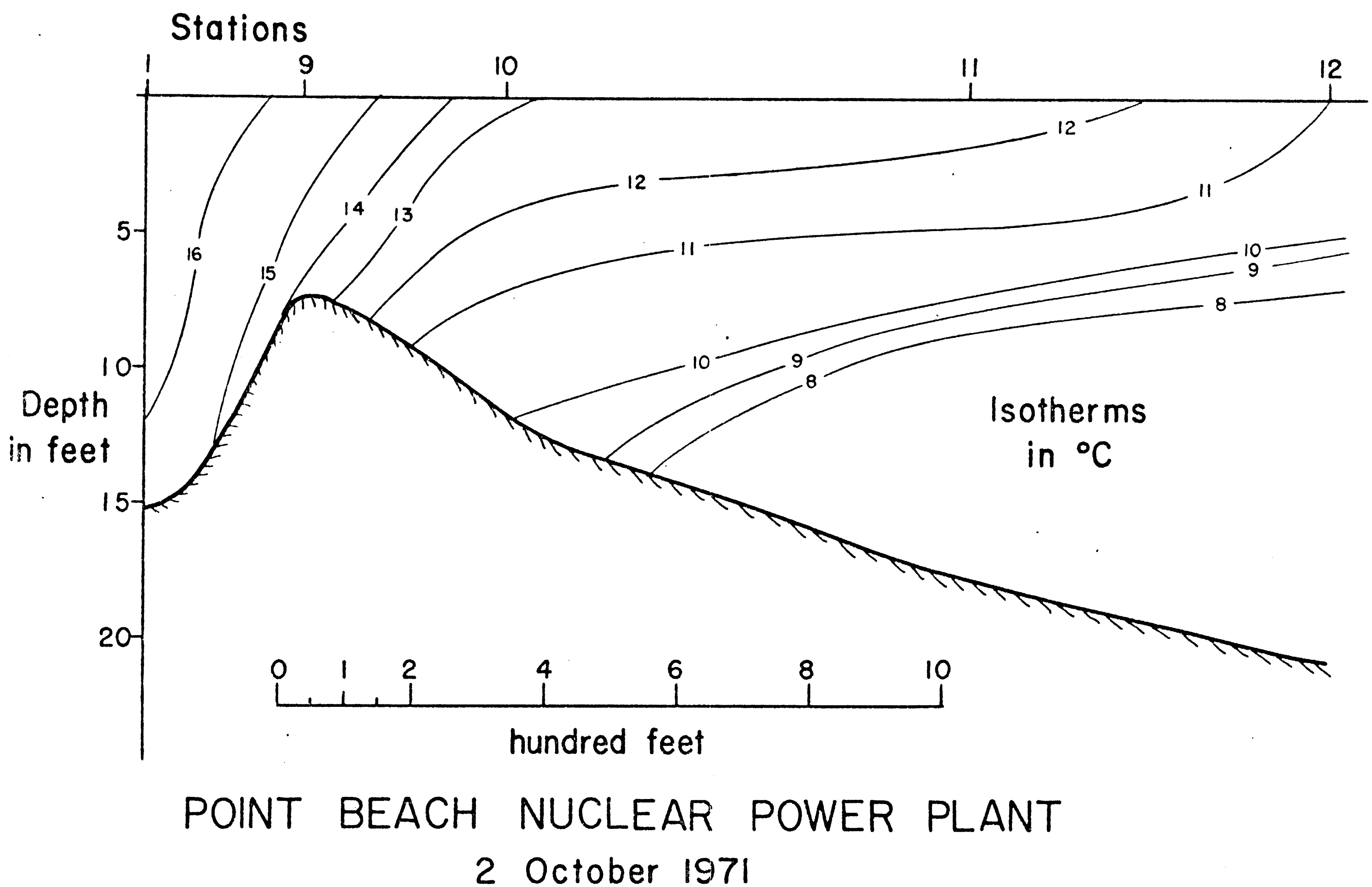
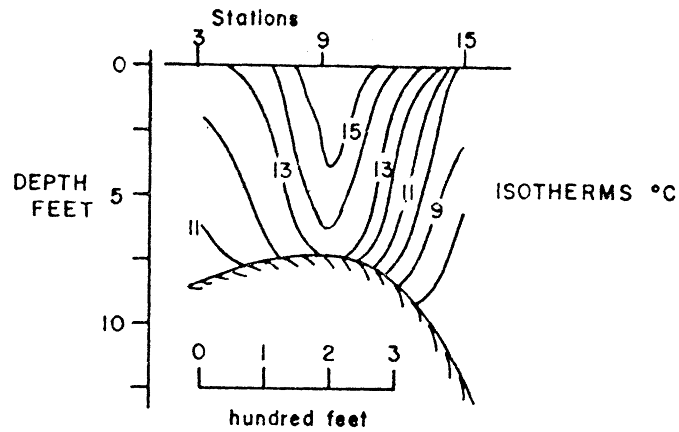
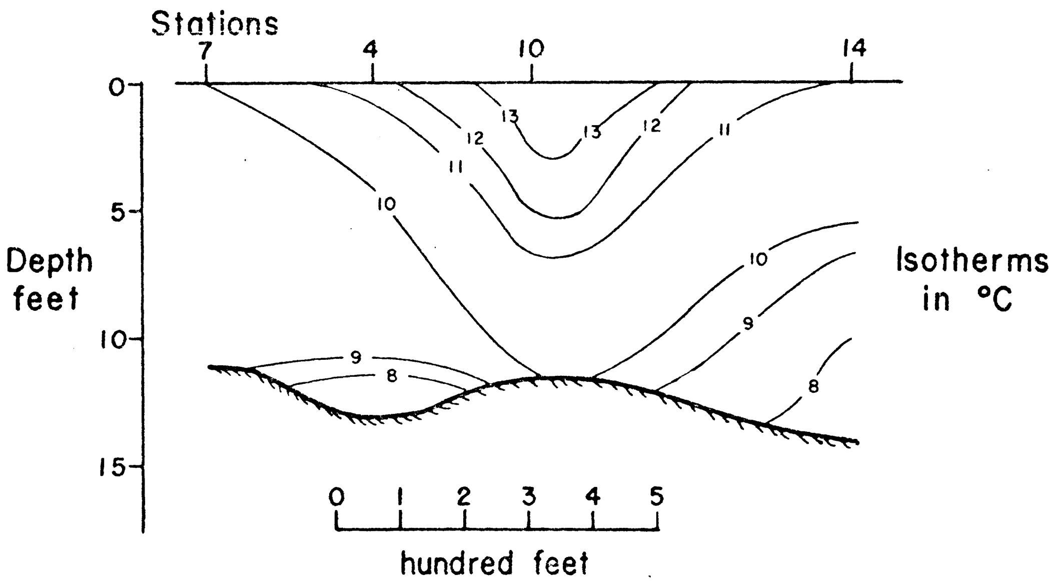


FIGURE 30. Point Beach, 2 X 71. Vertical Temperature Cross-section along Plume





POINT BEACH NUCLEAR POWER PLANT

2 October 1971

FIGURE 31. Point Beach, 2 X 71. Vertical Temperature Cross-sections across Plume

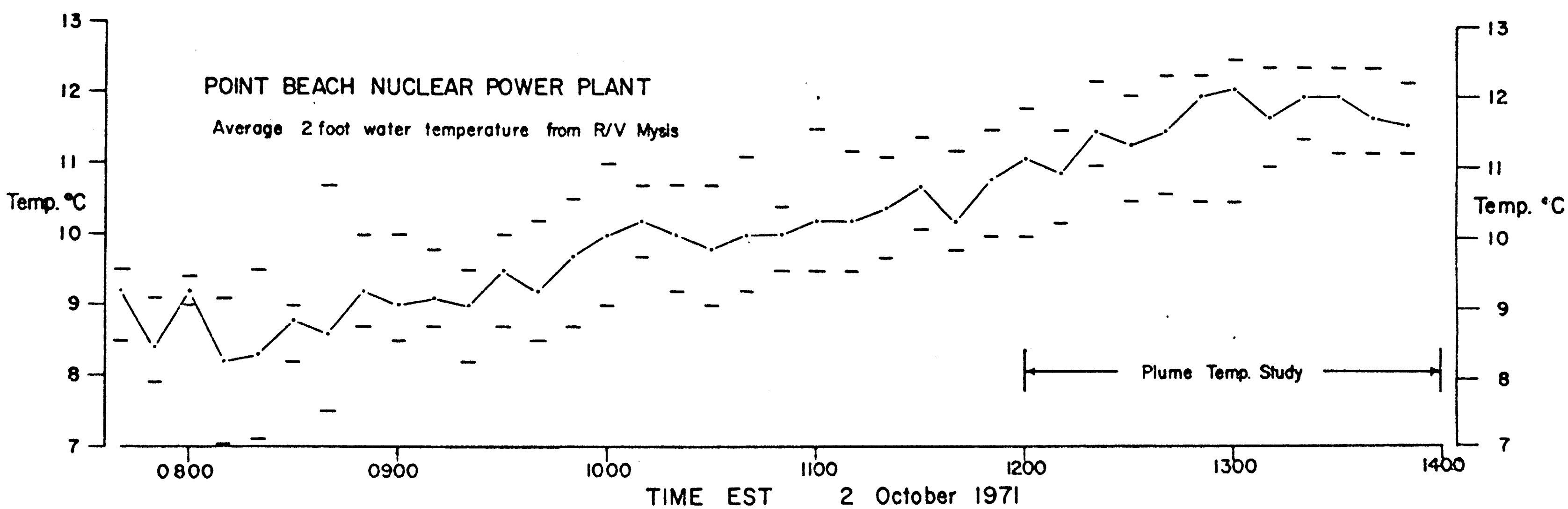


FIGURE 32. Point Beach, 2 X 71. Average (10 min intervals) 2-foot Water Temperature Record from R/V MYSIS

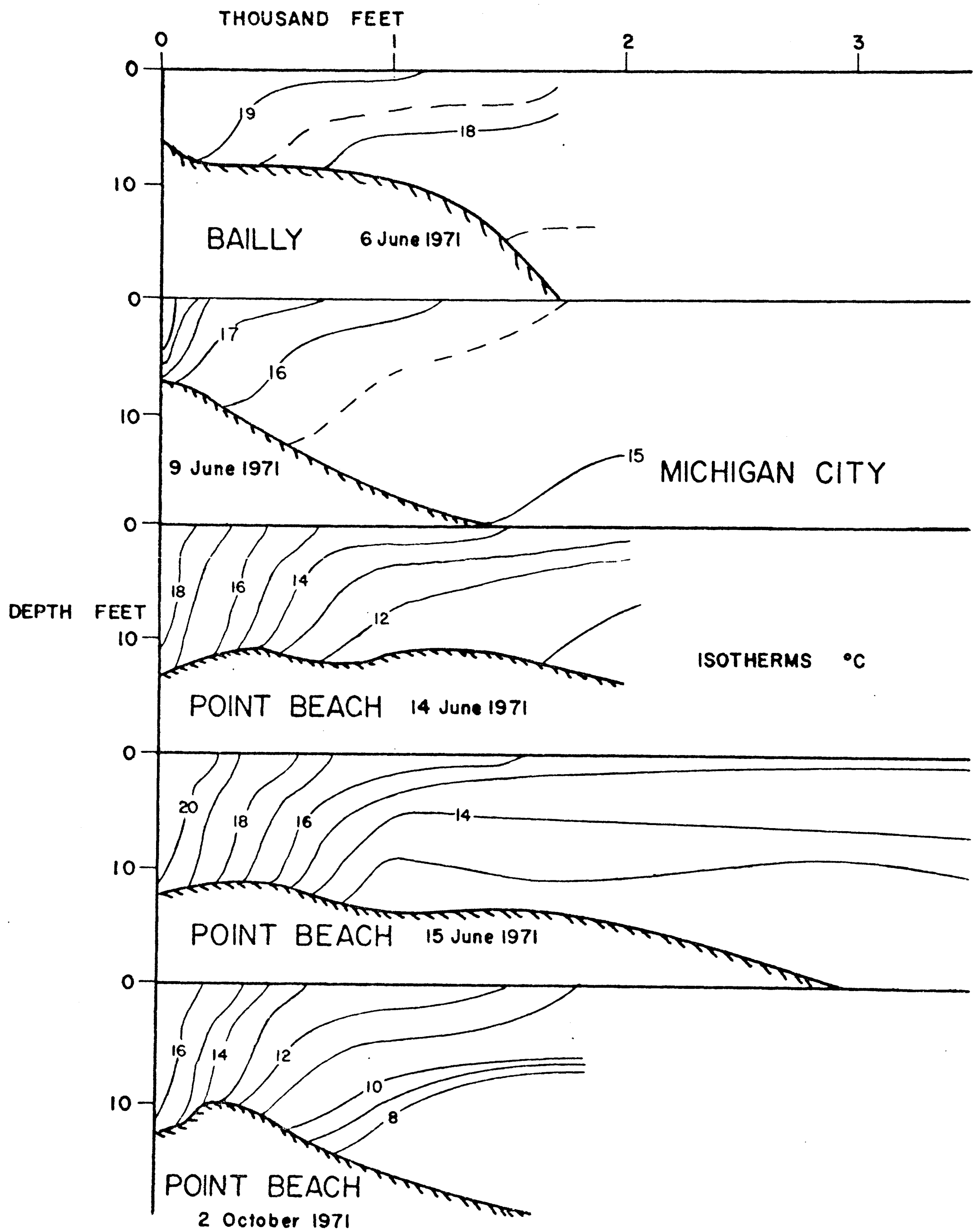


FIGURE 33. Summary; Vertical Temperature Cross-sections along Plume Axis: All Experiments 1971

C. THE ICE BARRIER AT THE COOK PLANT SITE

Shore ice monitoring by means of photographs began 13 December 1971 and continued through 3 April 1972. Biweekly surveys covering the beach immediately adjacent to the plant site with views to the west, north, and south were made at the Cook Plant site. Equipment intended to monitor shore ice conditions on a daily basis was field tested during this time period, and more extensive photographic surveys were made at the Cook Plant site on 5, 6, and 31 January 1972.

D. THE EFFECTS OF EXISTING THERMAL DISCHARGES ON LOCAL ICE BARRIERS

A photographic survey of shore ice conditions at the Campbell Power Plant outfall area was conducted on 1 February 1972. An aerial photographic survey of shore ice conditions along the southeastern coast of Lake Michigan between Grand Haven and the Bailly Plant was conducted on 22 February 1972. This material will be covered in Part XI.

Information obtained from these surveys will appear in the WINTER OPERATIONS REPORT which will be part XI of our report series.

APPENDIX

During the 1970 experiments on survey of existing thermal plumes, the necessity to improve our experimental techniques was realized. Among the needed improvements was a better instrument to measure the three dimensional structure of the thermal discharges. In the winter months of 1970-71 an electric bathythermograph (EBT) was constructed for use in our 1971 plume surveys. The instrument is designed specifically for shallow water work. It has a depth range to 200 ft with accuracy of better than 6 inches. The temperature range is from $-5^{o}C$ to $45^{o}C$ with accuracy of $\pm 0.1^{o}C$. The outputs of the sensors are conditioned by a pair of solid state operational amplifiers which serve as noise filters, decoupler and driver between the sensors and recorder. The gains of the amplifiers may also be adjusted to provide a signal level proper to individual recorders and sizes of recorded trace. It thus provides an extremely flexible system, allowing the operator to optimize the output for the conditions as required.

The physical arrangement of the sensors are given in Fig. 1'. The finished product is 1 7/8 inches diameter by 8 inches long with an 8 conductor cable on the end for power and signal transmission. A mounting bracket for attachment to a wire cable for deep operation is provided on the side. For shallow operation up to 30 ft the 8 conductor cable served as the support cable as well.

The depth sensor is a bonded strain-gage stainless steel diaphragm type pressure transducer. It is a commercially available unit whose specifications are given in Table 1.

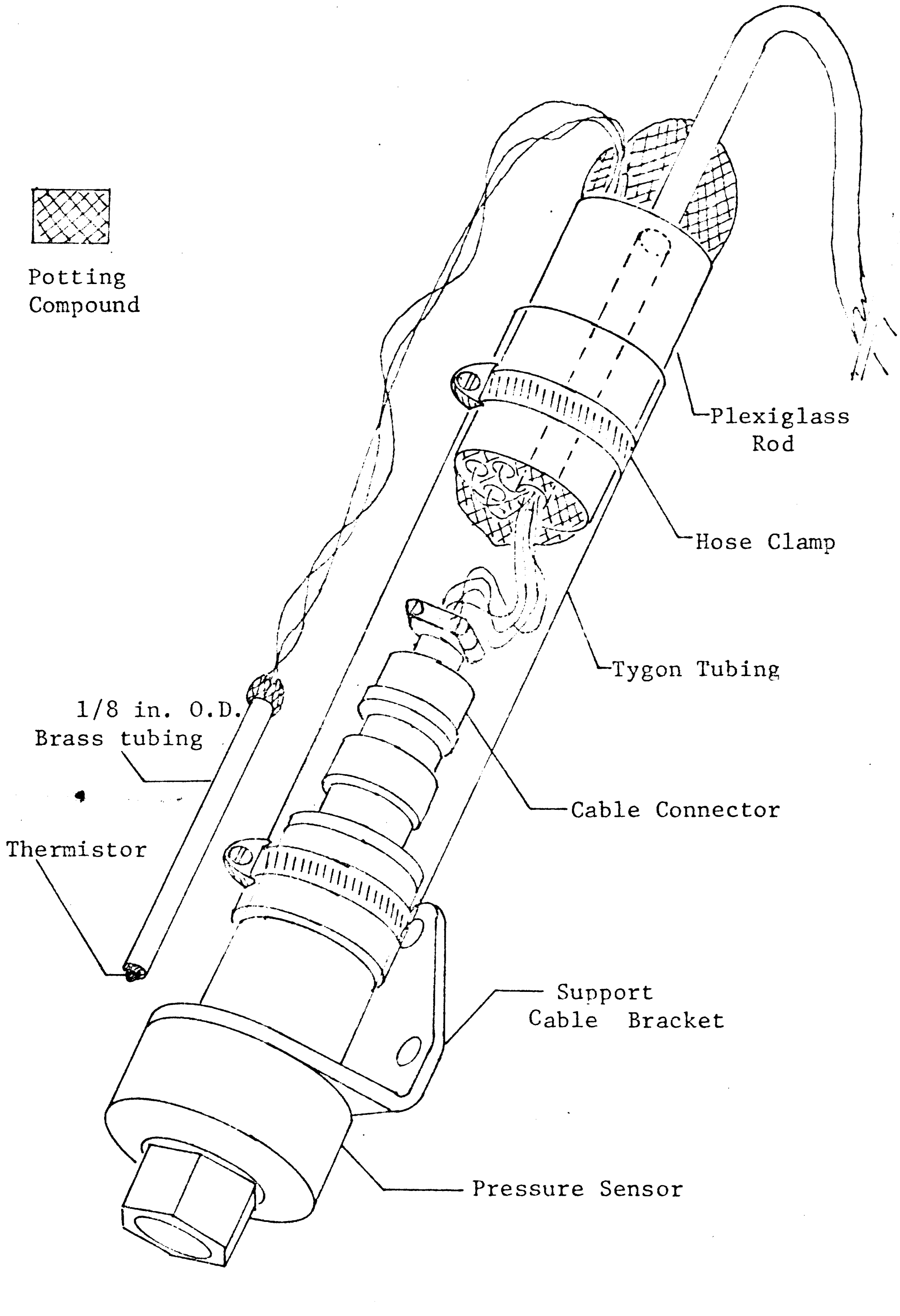


Figure 1. Sketch of E. BT. Sensors Assembly

TABLE 1'. Specifications of Teledyne Taber Model 187 Pressure Transducer.

Pressure range	0-100 PSIA (~230·7 ft H_2O)
Proof pressure	500 PSI causes no change in unit specifications
Burst Pressure	1500 PSI
Excitation	10.0 UDC or AC
Fullscale output	30 ± 0.15 mv (~0.130 mv/ft)
Repeatability	within 0.03 mv
Hysterisis	Less than 0.075 mv
Thermal Zero shift	Less than 0.006 mv/°C
Thermal sensitivity shift	Less than 0.003 mv/°C over the compensated temperature range of -35°C to 75°C
Natural frequency	3000 hz
Output impedence	350 ± 5.0 ohms

The electronic circuit employed with the pressure sensor is given in Fig. 2'. The 250 K potentiometer is set to give an amplifier gain of 7.69 so that the nominal output of the amplifier is 1.0 millivolt per foot of water. The pressure sensor was not calibrated in the laboratory. The calibration supplied by the manufacturer for this particular individual sensor is accepted. The signal

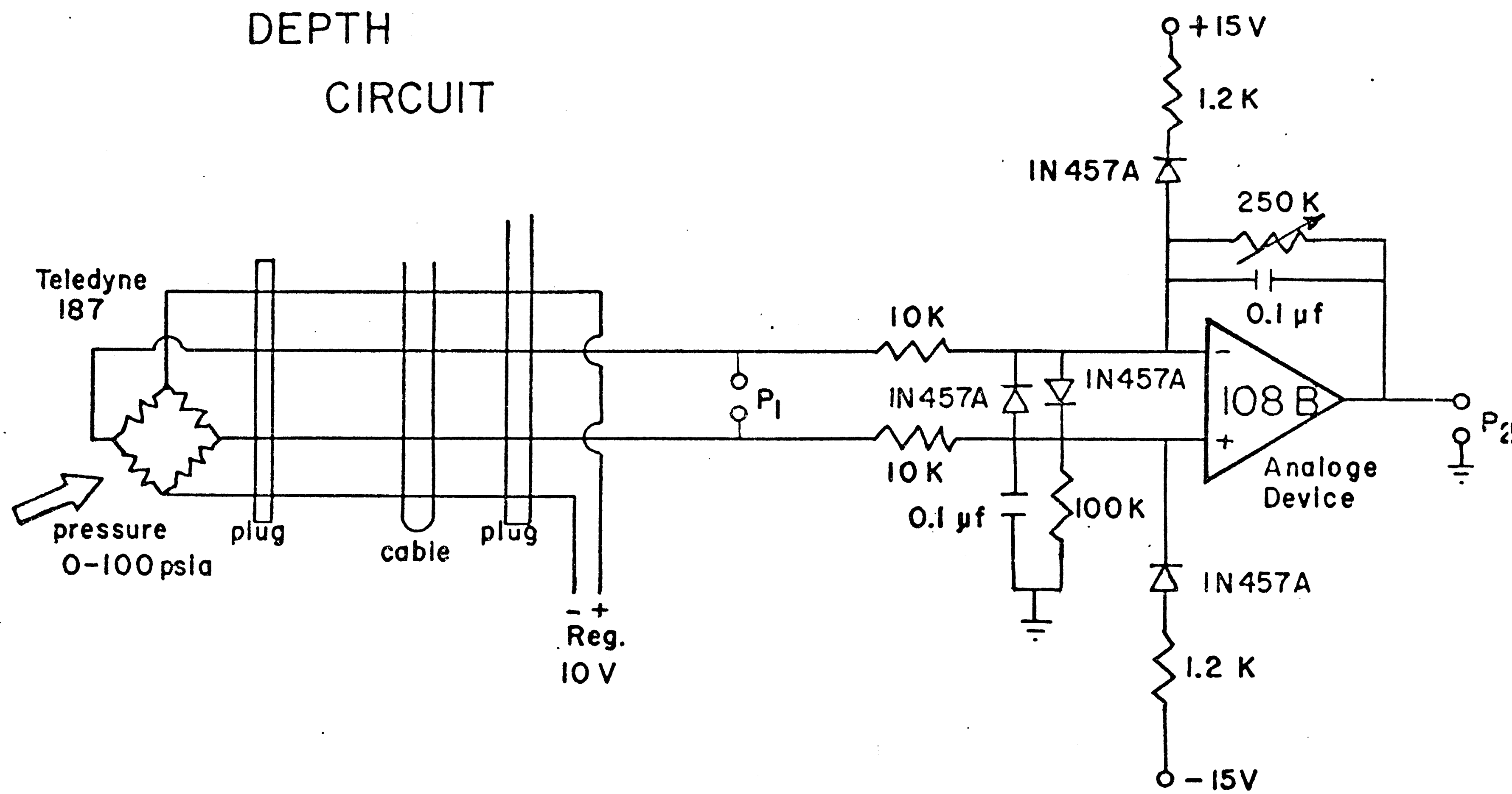


FIGURE 2. Depth Measuring Circuit

cable was measured and marked at 10 ft intervals. The X-Y recorder controls were further set in the field by lowering the sensor to one of the predetermined depths and thus compensating for any line attenuation and sensitivity shift.

The Temperature sensor employed is a Yellow Springs Instruments Co. Model 44202 Thermilinear thermistor. The specification given by the manufacturer is reproduced on the next page. The thermistor was further calibrated in the laboratory against a National Bureau of Standards calibrated mercury thermometer, by immersing both the thermistor and the NBS thermometer in a well stirred water bath contained in a covered Dewar flask. The output was recorded from the display on a digital voltmeter. The regression coefficients calculated from these results were used to check the constants given by the manufacturer. For the sensor used on our EBT, we found the circuit equations to be:

$$E_{out\ 1} = E\ in\ [\ -mt\ -b]$$

$$E_{out\ 2} = E\ in\ [\ mt\ +b'\ ]$$

where

$m = 0.005889$

$b = 0.8125$

$b' = 0.1875$

The new values obtained were then used to calculate the input voltages set for the thermistor network. The final temperature sensor with proper voltages and amplifier settings was then again calibrated against the NBS thermometer. This calibration is tabulated in Table 2' and plotted in Fig. 3'. The slope on this

YSI Thermilinear® Component

YSI Part #44202

Range −5° to +45°C

This Thermilinear Thermistor Network is a composite device consisting of resistors and precise thermistors which produce an output voltage linear with temperature, see Fig. 1, or a linear resistance with temperature, see Fig 2. The precise thermistors can either be the YSI #44018 (as included in the #44202) or they can be a YSI 700 Series Probe since they are electrically identical.

Equations which describe the behavior of the device are:
(Refer to Fig. 1)

$Eout_1 = (-0.0056846\ Ein)\ T + 0.805858\ Ein$

$Eout_2 = (+0.0056846\ Ein)\ T + 0.194142\ Ein$

(Refer to Fig. 2)

$R_T = (-32.402)\ T + 4593.39$

$T = °C$

SPECIFICATIONS

	Voltage Mode	Resistance Mode
Thermistor Absolute Accuracy and Interchangeability:	±0.15°C	±0.15°C
Linearity Deviation:	±0.065°C	±2.11 ohms
Ein Max	3.50 Volts	
$*I_T$ Max		615 ua
Sensitivity:	0.0056846 Ein/°C	32.402 ohms/°C
Load Resistance:	1 Megohm or more	
Time Constant:	The time required for the thermistor to indicate 63% of a new impressed temperature, in 'well stirred' oil, 1 sec; in free still air, 10 sec.	

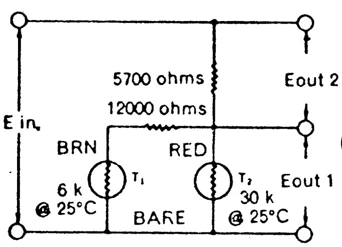


Fig. 1

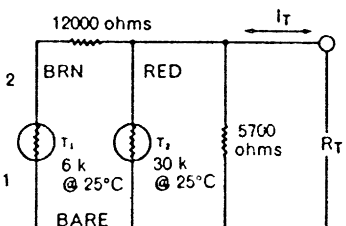


Fig. 2

*Ein Max. I_T Definition:

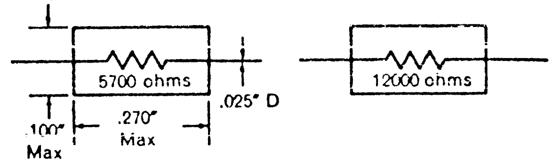
Ein Max. I_T Max values have been assigned to control the thermistor self-heating errors so that they do not enlarge the component error band; i.e., the sum of the linearity deviation plus the probe tolerances.

Ein Max, I_T Max values are assigned using a thermistor dissipation constant of 8MW/°C in stirred oil. If better heat-sink methods are used or if an enlargement of the error band is acceptable, Ein Max, I_T Max values may be exceeded without damage to the thermistor probe.

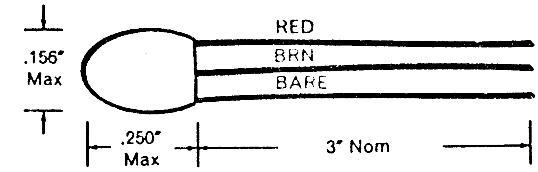
U S. Patent #3316765, Canadian Patent #782790

YELLOW SPRINGS INSTRUMENT CO.
YELLOW SPRINGS, OHIO 45387

YSI Resistor Composite #44302



YSI Thermistor Composite #4401



#44202
−5° to +45°C
$R_T = (-32.402)\ T + 4593.39$

°C	Ohms
-5	4753.4
0	4595.0
5	4432.7
10	4269.2
15	4106.0
20	3944.0
25	3783.0
30	3622.5
35	3461.0
40	3298.4
45	3133.3

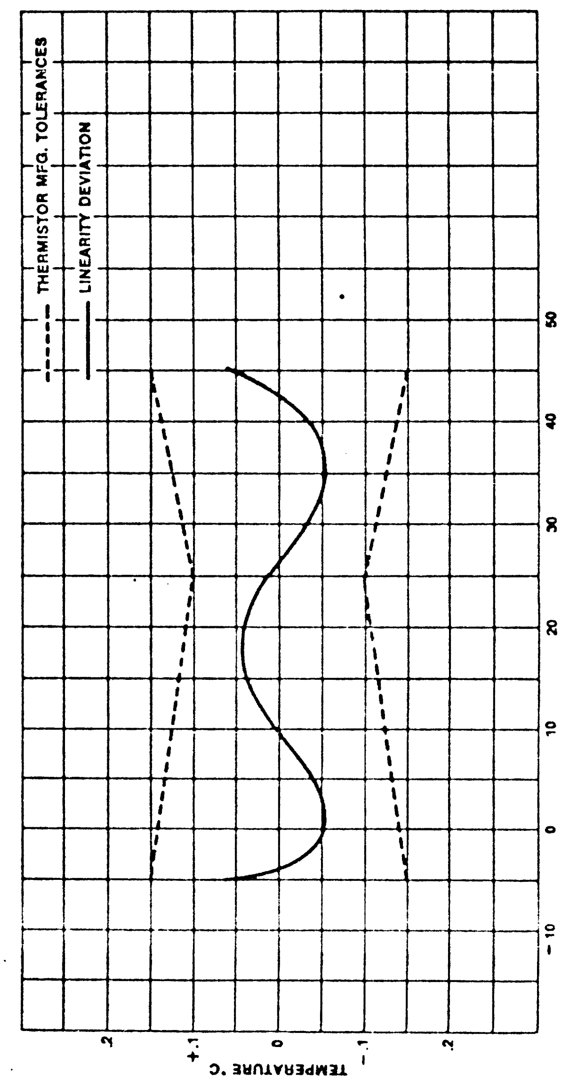


TABLE 2'. Calibration of EBT

Bath temp C°	Amplifier output mv
0.20	-74
2.40	-64
3.30	-59
6.85	-42
9.15	-32
12.40	-13
14.05	-4
16.10	4
18.30	14
20.30	26
22.95	41
25.10	50
27.20	61
29.20	71
30.90	77
33.60	92
36.10	105

Thermometer used: #19245-1A

Voltmeter used: Dynascan Mod. 111 (Digital)

Endpoint Voltages set at: +0.615 volts, -0.234 volts

Expected output: 0 mv at 15°C, 100 mv at 35°C

End Point voltages reading at end of calibration: +0.616 v., -0.235 v

Slope calculated by least squares regression: 5.0031 mv/°C

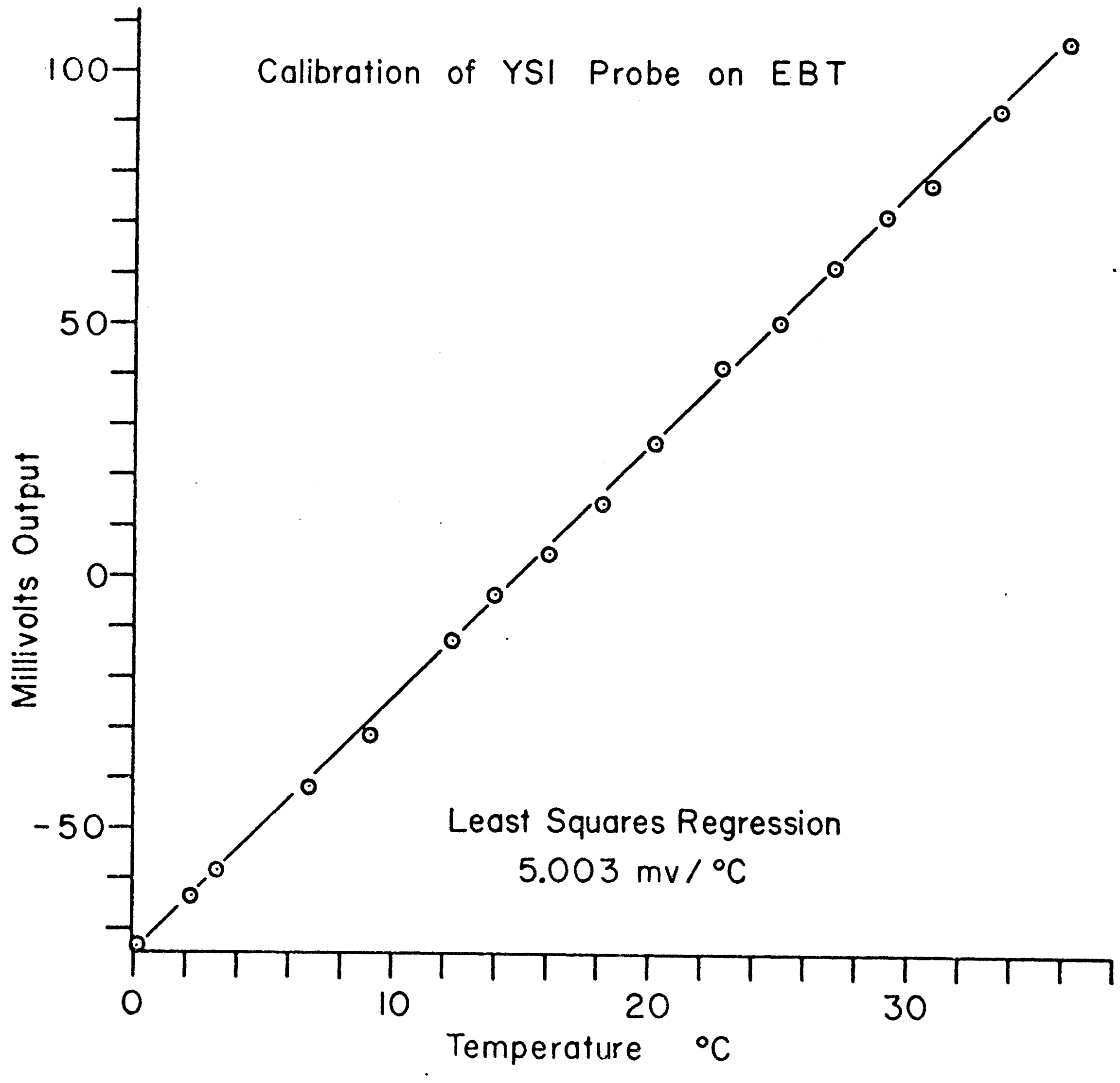


FIGURE 3. Calibration of Temperature Sensor

calibration curve is 5.0031 mv per ^{o}C, calculated from 17 pairs of observations whose correlation coefficient is 0.9998.

The circuit employed by the temperature sensor and amplifier is shown in Fig. 4! The circuit features two voltage regulators for the thermistor network and an amplifier operating as a voltage follower with gain. It also transforms the high output impedence of the thermistor network to the low output impedence of the amplifier for driving the recorder and indicators. Furthermore, a computation program is available for calculating the end point voltages for any desirable full scale temperature ranges and output voltages as required by the user. The only limitation is that the sum of the end point voltages applied to the thermistor net work is less than 3.0 volts for proper power dissipation.

The regulators and general equations for computation of the end point voltages were developed by Dr. Julian Pike of National Center of Atmospheric Research for their Boundary Profile System which the author had the privilege to evaluate in the summer of 1969.

The completed EBT was then given a response test. A time response for the pressure sensor was not tested since we lacked the necessary apparatus for the test. However, given the natural frequency of the sensor, one may calculate the response time assuming a damping factor of 0.64 for the pressure system. For the pressure transducer chosen, the response time thus calculated is about 250 micro-seconds. A damping factor of 0.64 produces the best overall frequency response

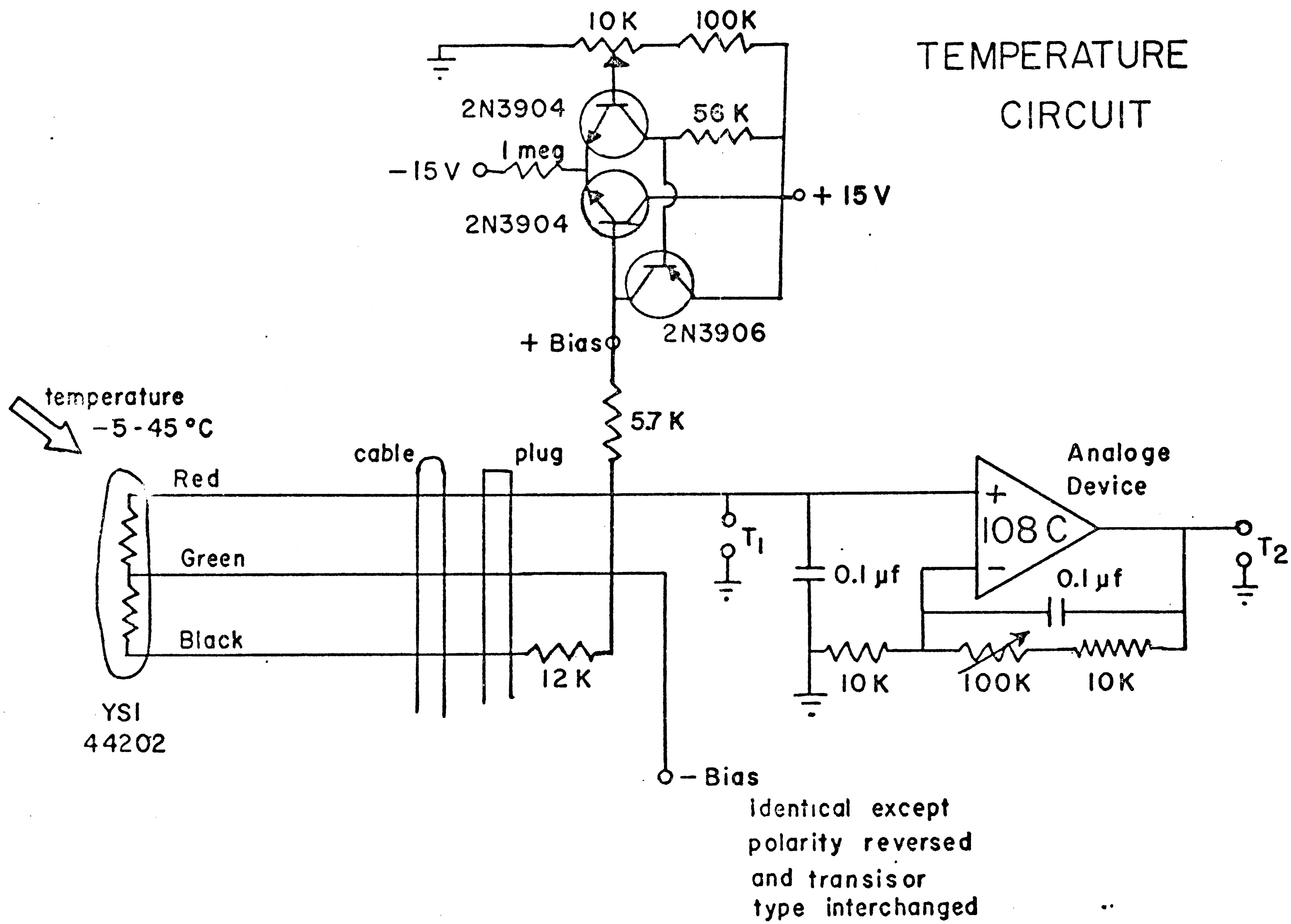


FIGURE 4. Temperature measuring circuit

for a second order system such as that of a spring diaphragm. The actual response of the sensor to a step change may be checked later with the aid of a slack tube manometer.

The temperature response is tested by switching the sensor from room temperature bath to a heated bath and vice versa. One of these response traces is reproduced in Fig. 5! The time constant for the system obtained is 1.2 seconds. This time is longer than that given by the manufacturer because of the added thermal mass from the support structure. These tests show that it will take four seconds for the system to indicate 95% of a step change. The temperature response is slower than we desire, but adequate for what we need.

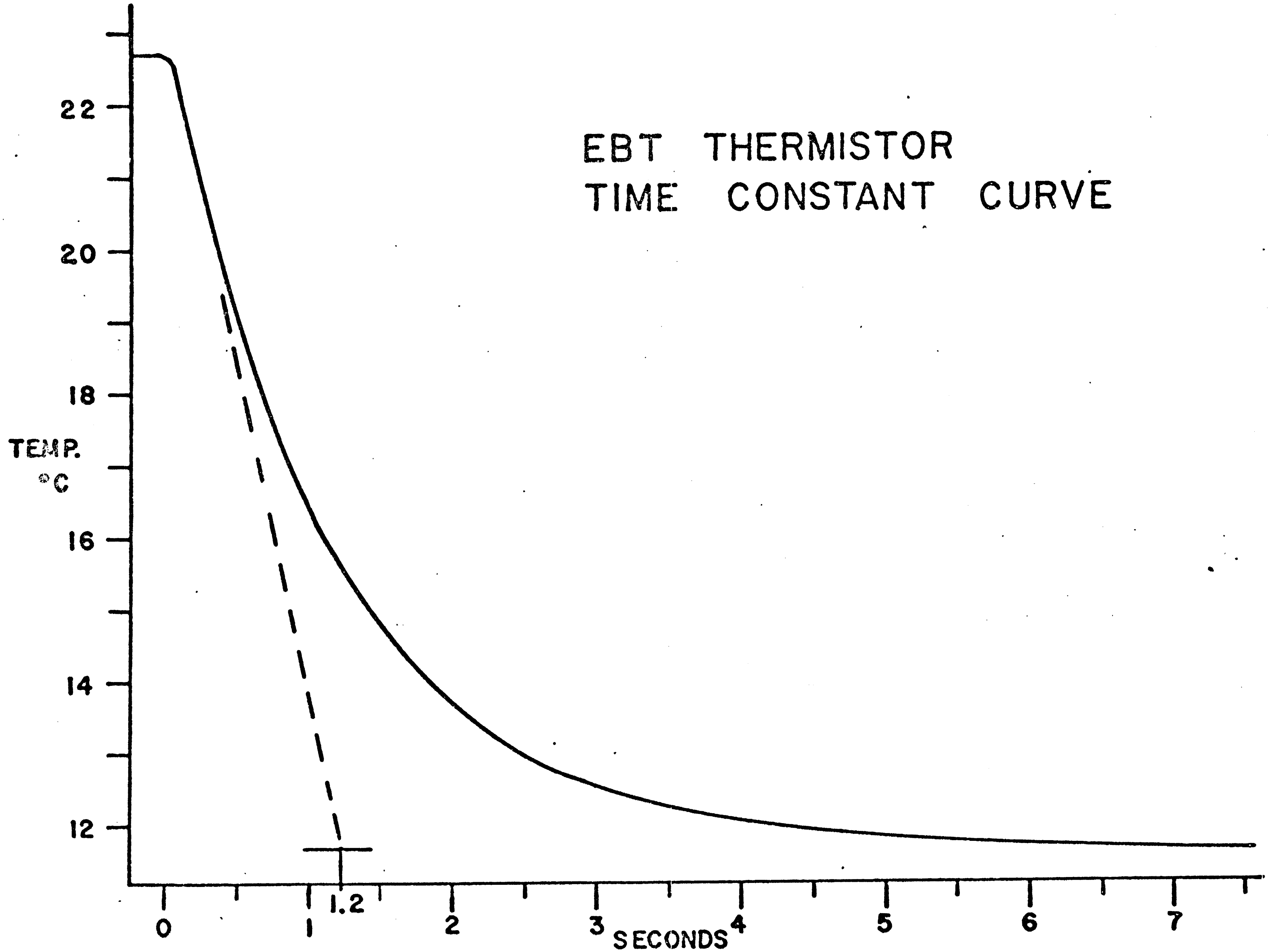


FIGURE 5' Step response of Temperature System